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Evaluation of Proposed TG and E (Tucson Gas and Electric Company) Wastewater Discharge on Groundwater in the Tucson Basin

Kenneth D. Schmidt, Fresno, Calif.

Prepared for

Environmental Protection Agency, San Francisco, Calif.

30 Nov 77

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EVALUATION OF PROPOSED TG&E WASTEWATER DISCHARGE ON GROUNDWATER IN THE TUCSON BASIN

prepared for

U.S. Environmental Protection Agency

San Francisco, California

by

Kenneth D. Schmidt
Groundwater Quality Consultant
Fresno, California

November 30, 1977

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The purpose of this investigation is to evaluate the probable impact of a proposed discharge of cooling tower blowdown wastewater on groundwater in the Tucson Basin. The sources of the wastewater is the Tucson Gas and Electric Company. About 740,000 gallons per day of wastewater are propsed to be dishcharged into an unnamed arroyo which eventually flows into the Santa Cruz River.

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November 30, 1977

Mr. Tom Kremer
Enforcement Division
U.S. Environmental Protection Agency
215 Fremont Street
San Francisco, CA 94105

Dear Mr. Kremer:

Enclosed are ten copies of the final report on the Tucson Gas and Electric Company proposed wastewater discharge from the Irvington Station in the Tucson Basin. It has been a pleasure to perform this investigation and we appreciate the cooperation of all concerned.

Sincerely yours,

Kenneth D. Schmidt

Kenneth D. Schmidt

KDS:mk

Enclosures

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CONCLUSIONS

1. Areas potentially impacted by the proposed discharge include: (a) near the proposed discharge site just above Alvernon Way, (b) along the unlined part of Julian Wash which extends downstream to the Tucson Diversion Channel, and (c) a reach several miles long near the confluence of Julian Wash and the Santa Cruz River.

2. Groundwater near the proposed discharge site is used primarily for industrial (cooling water) and domestic purposes. Groundwater along the unlined section of Julian Wash is largely not developed at present because of poor aquifer characteristics. Groundwater near the confluence of Julian Wash and the Santa Cruz River is used primarily for domestic purposes.

3. The chemical quality of groundwater in the potentially impacted area is excellent for domestic, industrial, and irrigation use except for high hardness and occasionally high fluoride contents. Total dissolved solids contents average about 400 to 500 mg/l near the proposed discharge site and along Julian Wash. Total dissolved solids contents average about 400 to 700 mg/l along the Santa Cruz River near Julian Wash.

4. Constituents in the wastewater that occur at sufficient concentrations to present a potential threat to groundwater quality include: total dissolved solids, sulfate, fluoride, and hardness. Of these parameters, only fluoride has been given a maximum contaminant level by the U.S. Environmental Protection Agency in the National Interim Primary Drinking Water Regulations.

5. The impact of the proposed discharge on groundwater quality is highly dependent on the infiltration rate of wastewater in both Julian Wash and the Santa Cruz River. Available data indicate that some infiltration may occur along the unlined part of Julian Wash and substantial infiltration is likely along the Santa Cruz River below Julian Wash.

6. The discharge of 742,000 gallons per day of such wastewater at a total dissolved solids content of 500 mg/l would have little or no measurable impact on groundwater quality in the Tucson Basin.

7. The discharge of 742,000 gallons per day of such wastewater at a total dissolved solids content of 1,000 mg/l would have some impact on groundwater quality in the Tucson Basin. The total dissolved solids contents of water pumped from several municipal and industrial wells near Irvington Station and several municipal wells near the confluence of Julian Wash and the Santa Cruz River could be increased several hundred mg/l.

8. The discharge of 742,000 gallons per day of such wastewater at a total dissolved solids content of 2,500 mg/l could have a significant impact on the quality of water pumped from some wells in the Tucson Basin. The total dissolved solids contents of water pumped from several municipal wells along the Santa Cruz River near Julian Wash could be increased up to 800 mg/l. Fluoride, sulfate, and hardness contents could also be increased significantly if the wastewater was of similar chemical composition to that of present cooling tower blowdown. Fluoride contents could exceed the maximum contaminant level. Increases in the other parameters are of esthetic concern, rather than health. Smaller increases in total dissolved solids content could occur in water pumped from TG&E wells at Irvington Station and one municipal well near the proposed discharge site.

9. No long-term buildups in salinity would result in the Tucson Basin groundwater from the proposed discharge because of the heavy pumping and mixing that would occur. The volume of pumpage greatly exceeds that of the waste discharge on an annual basis. Much of the pumped water is subsequently exported from the Tucson Basin after use, as sewage effluent in the Santa Cruz River channel.

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EVALUATION OF PROPOSED TG&E WASTEWATER DISCHARGE ON GROUNDWATER IN THE TUCSON BASIN

INTRODUCTION

In general, the purpose of this investigation is to evaluate the probable impact of a proposed discharge of cooling tower blowdown wastewater on groundwater of the Tucson Basin. The source of the wastewater is the Tucson Gas and Electric Company, Irvington Station, located in the northwest quarter of section 3, T15S/R14E. The station is immediately southwest of Davis-Monthan Air Force Base and six miles southeast of downtown Tucson. About 740,000 gallons per day (gpd) of wastewater are proposed to be discharged into an unnamed arroyo southwest of the facility. The discharge would flow about one-quarter mile in the arroyo to the confluence with Julian Wash. Julian Wash drains northwesterly to the confluence with the Santa Cruz River, about four and one-half miles from the proposed discharge point (Figure 1).

Specifically, the area of potential impact of the discharge on groundwater is to be delineated. The impact of the proposed discharge on total dissolved solids content of the groundwater is to be determined in a three-dimensional sense. Also, the probable effect of the discharge on present and potential uses of groundwater is to be determined. The cumulative impact of a long-term continuous discharge is to be emphasized. Three different total

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dissolved solids contents of the discharge are to be evaluated, namely 500 mg/l, 1,000 mg/l, and 2,500 mg/l.

EXISTING CONDITIONS

Regional Geology and Hydrology

Davidson (1973) reported on groundwater conditions in the Tucson Basin. The Tucson Basin is a 1,000 square-mile area in the upper Santa Cruz River drainage basin. The Tucson Basin is bounded on the north by the Tortolita and Catalina Mountains, on the east by the Rincon, Tanque Verde, and Santa Rita Mountains, and on the west by the Sierrita and Tucson Mountains. Elevations of the mountains on the north and east are generally 6,000 to 8,000 feet, whereas elevations of the mountains on the west are 3,000 to 6,000 feet. The plain of the Tucson Basin slopes northwest from 2,900 feet elevation in the upper part to 2,000 in the lower part. The Tucson urban area, relying solely on groundwater for its domestic supply, lies in the northwest part of the basin.

Geology

Igneous, sedimentary, and metamorphic rocks crop out in the mountains and bound the Tucson Basin. Generally, these rocks are of low permeability and do not yield large amounts of water to wells. Tertiary and Quaternary sedimentary rocks in the basin form the aquifer and are of greatest interest in this investigation. Delineated units include the Pantano Formation, the Tinaja beds, the

Fort Lowell Formation, and surficial deposits, in ascending order. The Tinaja beds and Fort Lowell Formation yield large amounts of water to wells and supply most of the groundwater presently pumped in the Tucson Basin.

The Pantano Formation is typically a reddish-brown silty sandstone to gravel that is weakly to strongly cemented by calcium carbonate. The upper part of the unit generally includes gypsiferous mudstone. Most of the unit is Oligocene in age. The Pantano Formation is generally several hundred to a thousand feet thick and is slightly inclined or flat in the central part of the basin. In places, the formation has been highly offset by faulting. At depth in the Tucson Basin, the unit is a reasonably good aquifer.

The Tinaja beds unconformably overlie the Pantano Formation and are overlain by several hundred feet of alluvium in the Tucson Basin. These beds range up to several thousand feet in thickness. Sandy gravel is the predominant lithology near the mountain fronts; however, gypsiferous clayey silt and mudstone predominate near the central axis of the basin. The Tinaja beds filled a subsiding basin during Miocene and Pliocene time. The central part of the Tucson Basin is a triangular downfaulted block bounded by the Santa Cruz Fault on the west, a second fault parallel to Rillito and Tanque Verde Creeks on the north, and a third probable major northeast-trending fault on the southeast. The Tinaja beds in the down-faulted block are a clayey silt to mudstone in the lower part

and a clayey gravel to clayey silt in the upper part. The coarser-grained strata comprise an important part of the aquifer in the basin, particularly in areas where the overlying alluvium has been dewatered.

The Pleistocene Fort Lowell Formation unconformably overlies the Tinaja beds and is 300 to 400 feet thick beneath most of the Tucson Basin. The Fort Lowell Formation grades from a silty gravel near the mountain fronts to a silty sand and clayey silt in the central part of the basin. In most of the basin, the Fort Lowell Formation contains from 50 to 90 percent material coaser than silt. Sediment of the formation is loosely packed and weakly cemented. The contact between the Fort Lowell Formation and underlying Tinaja beds is generally marked by a substantial increase in cementation. The Fort Lowell generally has been affected only slightly by faulting. The Fort Lowell Formation crops out in part of the Tucson urban area, and a very thick, dense caliche layer is present just beneath the land surface. The Fort Lowell Formation is the most productive unit of the aquifer in the Tucson Basin.

Quaternary surficial deposits are mainly gravel and gravelly sand, and locally sand to sandy silt. These deposits overlie and partially conceal older sedimentary units. The deposits include both floodplain and terrace alluvium. Present-day flood plains are bounded by deposits comprising the Jaynes Terrace. Surficial deposits associated with the terraces average

about 30 feet thick, whereas those beneath the floodplains average about 50 feet thick. Deposits along the streams are loosely packed and generally not cemented. As the surficial deposits are usually above the water table, groundwater production from them is minimal.

Hydrology

Precipitation at Tucson International Airport averaged eleven inches from 1948-70 (Sellers and Hill, 1974).

De La Torre (1970) discussed streamflow in the upper Santa Cruz River Basin. Streams of the Tucson Basin are ephemeral in nature, and infrequent storm events are the primary source of streamflow. The Santa Cruz River flows north from near Nogales, to Tucson, and joins the Gila River south of Phoenix. The Santa Cruz River is normally dry near the confluence of Julian Wash, except for about forty days each year. Summer floods are more common than winter floods. Burkham (1970) discussed streamflow infiltration in the main channels of the Tucson Basin. Water levels are presently far below the stream channels, due to excessive pumpage of groundwater. Thus, recharge to groundwater can occur from seepage of streamflow. Streamflow is generally of excellent chemical quality (Laney, 1972). Wastewater from a gravel-processing plant in the Santa Cruz River floodplain south of Valencia Road can potentially influence flows near the confluence of Julian Wash.

Regional Groundwater

Davidson (1973) stated that the Tertiary and Quaternary sediments comprise a single aquifer. The main sources of recharge to groundwater in the Tucson Basin are infiltration of streamflow along the major channels and mountain-front recharge. The aquifer

ranges up to 2,000 feet in thickness. The upper part of the aquifer is more permeable than the lower part, and most wells in the urban area are less than 700 feet deep. Depth to groundwater ranges from less than 100 feet near the Santa Cruz River to more than 700 feet in the southeastern part of the basin (Osterkamp, 1973). The direction of groundwater movement is to the north and west, toward Rillito Narrows, where groundwater leaves the Tucson Basin. Brown (1976) reported on components of the water budget in the Tucson area for 1970-72. The primary source of discharge is by pumping wells and pumpage greatly exceeds recharge.

Wright and Johnson (1976) reported on water-level declines in the Tucson Basin. The City of Tucson pumps about 60 to 70 percent of its water from about 200 wells in the Interior Well Field in the main part of the basin. About 45 wells in the Southside and Santa Cruz well fields supply an additional 30 percent of the water supply, and the remainder comes from Avra Valley, to the west of the Tucson Basin. Total pumpage by the City of Tucson from the Tucson Basin in 1976 was about 56,000 acre feet. Irvington Station is the locale of the largest water-level decline in the urban area -- over 150 feet between 1947 and 1975. The total water-level decline in this area since 1947 was projected to exceed 175 feet by 1980.

Laney (1972) discussed the chemical quality of groundwater in the Tucson Basin. Most groundwater in the Tucson Basin contains less than 500 mg/l of total dissolved solids. Water above 700 feet in depth is usually a calcium-sodium bicarbonate type, is moderately hard to hard, and contains less than 1.0 mg/l fluoride. Water at

greater depth is usually a sodium bicarbonate type, is soft, and is of excellent chemical quality. However, water below about 1,000 feet in depth may contain fluoride in excessive amounts for public supply. Groundwater of the poorest quality for public supply is at shallow depths along the major streams, in the Pantano Formation along the northeast margin of the basin, at depth in gypsiferous mudstone, and along a narrow zone that trends northwestward across the basin. In such places, water may contain more than 1,000 mg/l total dissolved solids. There are a number of potential sources of degradation of groundwater quality in the Tucson Basin. These include agricultural return flow, mining and milling wastes, sewage effluent, storm runoff, and industrial wastes.

Site Specific Conditions

The major area of concern in this investigation extends from the TG&E Irvington Station northwest along Julian Wash to the Santa Cruz River (Figure 1).

Surface Water

The average discharge of the Santa Cruz River at Tucson was 15,700 acre-feet per year from 1905-65 (De La Torre, 1970). Streamflow in Julian Wash was discussed as part of the Santa Cruz Riverpark Master Plan (City of Tucson, 1977). The drainage area of Julian Wash above Interstate I-19 is 46 square miles. About 18 square miles lie above the Ajo Way Detention Basin. The Tucson Diversion Channel connects the detention basin with Julian Wash. The channel is lined between the detention basin and Julian Wash, and Julian Wash is lined from the channel to the mouth.

According to the City of Tucson (1977), runoff at the mouth of Julian Wash during the summer is estimated to be at least 250 acre-feet each year. It would exceed 750 acre-feet once every two years, and 1,900 acre-feet once every ten years. Winter runoff is estimated to exceed 100 acre-feet each year. It would exceed 400 acre-feet once every two years and 1,100 acre-feet once every ten years. Total runoff (summer and winter) at the mouth of Julian Wash would thus exceed 350 acre-feet every year, and 1,150 acre-feet once every two years. Burkham (1970) calculated an average annual runoff of 1,020 acre-feet for a 48.1 square mile watershed of Julian Wash. The mean total dissolved solids content of runoff in Julian Wash is estimated to be about 200 mg/l, based on data collected from nearby watersheds. The City of Tucson (1977) stated that runoff from Julian Wash could be stored in a detention basin between Interstate I-19 and the Santa Cruz River. Such water could be used for irrigation, recreation, or groundwater recharge.

Soils

Soils in the vicinity of lower Julian Wash belong to the Rillino-Latene-Cave association (Richardson and Miller, 1974). This association occurs primarily on uplands of the Tucson Basin, above the floodplains. The soils are calcareous and commonly contain caliche or hardpan. Detailed soil mapping is presently in progress in the Tucson Basin, but the results will not be published for some time. The Cave soils, which occur in downtown Tucson, have a dense, concrete-like, lime hardpan which appears to be impermeable. Rillino and Latene soils, which are more

predominant near Julian Wash, also contain some lime. However, the layers are generally soft and also tend to be fractured. These soils thus appear to have a higher permeability than the Cave soils.

A number of 25-foot deep test holes were drilled in 1960 along the east boundary of section 34, T14S/R14E (Arizona Testing Laboratories, 1960). Caliche was commonly encountered in the upper ten feet; however, some holes did not encounter caliche in the 25-foot interval. In most cases where the caliche was encountered, it was not the dense, compact type. Southwest Testing and Research Laboratory (1956) reported on six 10-foot deep test holes drilled at Irvington Station. Three of the six holes encountered caliche in the upper four feet, whereas the other three holes did not encounter caliche.

Caliche is commonly logged by well drillers, due to its distinctive character. A review of drillers' logs in the vicinity of Julian Wash indicates an abundance of caliche, particularly in the upper 10 or 20 feet of the subsurface. However, these layers do not appear to be continuous.

Some of the most comprehensive data on the lithology of near-surface materials were obtained during exploratory borings for structures located along Interstate I-10. The Arizona Department of Transportation has detailed lithologic information for the Tucson Diversion Channel and Campbell Avenue, Interstate I-19 interchange, and the 29th Street crossing. Borings near the diversion channel and Campbell Avenue indicate that caliche is always present in the upper ten feet of material. Most of the holes were about 15 to 20

feet deep, although one extended to 30 feet depth. The bottom of the caliche is commonly at a depth of 6 to 8 feet. A second caliche layer was present in some holes in the 10-15 foot depth interval. Geologist logs indicate that a dense hardpan is sometimes present, but is only several feet thick. The caliche in this area is generally not the dense, compact type and is underlain by sand, gravel, and cobbles. Several borings near the Interstate I-19 interchange extended to 30 feet depth. These borings indicated a much greater thickness of caliche along the mouth of Julian Wash than near Campbell Avenue. Caliche commonly extended to depths of 15 to 20 feet, and occasionally to 30 feet. This caliche appears to grade with depth into the dense, compact type and is also underlain by sand and gravel. Borings near the 29th Street crossing indicated abundant caliche in the 5 to 30 foot depth interval. This caliche is the dense, compact type and is underlain by sand and gravel.

Groundwater

Some of the deepest water wells in the Tucson Basin have been drilled at Irvington Station. Figure 2 shows well locations and hydrogeologic conditions in the area of interest. Table 1 summarizes construction data for TG&E wells. Davidson (1973) presented a subsurface geologic cross section (F-F') extending from southwest to northeast through Irvington Station. TG&E Well No. 6 and Test Hole No. 7 and Ray Water Company No. 3 were included in this section. The surficial deposits are about 20 to

TABLE 1--DATA FOR TG&E IRVINGTON STATION WELLS (T15S/R14E)

State Well No.	Date Drilled	Method	Total Depth (Feet)	Depth Casing (Feet)	Diam. Casing (Inches)	Perforations (Feet)
2cac (No. 5)	12/59	Rotary	2,500	2,057	16	1,000-2,500
2dbc (No. 7)	9/63	Rotary	3,145	None	None	None
3aba (No. 3A)	9/74	Cable Tool	1,000	1,000	20	350-1,000
3acb (No. 2A)	9/74	Cable Tool	1,008	1,008	20	350-990
3acd (No. 8)	9/70	Rotary	1,044	1,044	20	446-1,044
3bbb (No. 4)	9/59	Cable Tool	868	868	20	240-858
3bdb (No. 1)	9/56	Cable Tool	1,120	1,120	16	240-1,108
3dad (No. 6)	9/63	Rotary	2,505	2,502	18, 14, 12	800-2,502

Data from Arizona State Land Dept. and TG&E files. Well locations shown on Figure 2. Well No. 7 was test hole and not completed as a production well.

30 feet thick near Irvington Station and the Fort Lowell Formation extends to a depth of about 300 feet. The Tinaja Formation extends to a depth of about 1,400 feet and the Pantano Formation extends to depths exceeding 3,000 feet at Irvington Station. Davidson indicated that a northwest-trending fault passes beneath Irvington Station. Southwest of this fault, the Tinaja Formation extends over 1,900 feet in depth and contains abundant gypsiferous silt below the 700-foot depth. The portion of the basin between this fault and the Santa Cruz River Fault to the west is interpreted as a down-faulted block. Northeast of the northwest-trending fault, the Pantano Formation occurs at shallower depths and has been tapped by deep TG&E wells. The fault does not apparently affect the Fort Lowell Formation or water levels in the major aquifer.

Cross section C-C' extends from west to east through the area near the confluence of Julian Wash and the Santa Cruz River. The surficial deposits beneath Julian Wash are about 20 feet thick. The Fort Lowell Formation extends to about 250 feet in depth and comprises the major aquifer in the vicinity. The Tinaja Formation extends to about 550 feet in depth and is underlain by a hard-rock unit.

Water-level measurements for TG&E wells indicate that for the "shallow" wells (approximately 1,000 feet deep), static levels declined from about 200 feet in 1960 to between 290 and 300 feet depth in 1976. The water-level decline thus averaged about five feet per year. At present, the Fort Lowell Formation has largely been dewatered and the "shallow" wells produce entirely from the

Tinaja beds. Water levels measured in the two "deep" wells (about 2,500 feet deep) indicate that hydraulic heads are presently about 40 to 70 feet below those in the shallow part of the aquifer. Thus, the vertical direction of groundwater movement is downward in the vicinity of Irvington Station.

The regional direction of groundwater movement (Figure 2) in the vicinity of Irvington Station in 1970 was to the north-northwest (Matlock and Davis, 1972). However, a localized cone of depression had developed in the vicinity of Irvington Station by 1970. The local direction of groundwater movement beneath Julian Wash and near the proposed discharge point was to the northeast. The slope of the water table was about 90 feet per mile. Although water levels have declined about 35 feet since 1970, the direction of groundwater movement is presently similar to that of 1970. Elevation of the water table beneath Irvington Station is presently about 2,340 feet.

Near the confluence of Julian Wash with the Santa Cruz River, static water levels were about 100 feet deep and water level elevations about 2,300 feet in 1975. Thus, groundwater levels beneath Julian Wash become progressively shallower as the confluence with the Santa Cruz River is approached.

Anderson (1972) presented data on aquifer characteristics used in an electrical-analog model for groundwater in the Tucson Basin. Much of these are based on pump tests conducted in the mid-1960's. These data indicate specific capacities for wells near Irvington Station ranged from about 20 to 35 gpm per foot of drawdown. Transmissivity ranged from about 30,000 to 55,000 gpd per foot. Few large-capacity wells are present along Julian Wash

between Palo Verde Road and South Campbell Avenue and this is an area of poor groundwater production as shown by City of Tucson Test Hole WR-9 (Figure 2). Specific capacities are presently estimated to be less than 10 gpm per foot based on City of Tucson data. Aquifer transmissivity was less than 10,000 gpd per foot between South Campbell and South Park Avenues. Between South Park and the Interstate I-19 interchange, aquifer transmissivity ranged from 10,000 to 50,000 gpd per foot. Near the Santa Cruz River, transmissivity ranged from 50,000 to more than 180,000 gpd per foot. Water-level declines in most areas since the pump tests were conducted have reduced the specific capacities and transmissivities due to a decrease in saturated thickness.

About 4,400 acre-feet of water, primarily for cooling purposes, were pumped by TG&E from seven wells near Irvington Station in 1976. The Ray Water Company has five active municipal wells for domestic supply south of Julian Wash between Palo Verde and Swan Roads (Table 2). These wells are about 500 feet deep, have shallow perforations, and thus tap the Fort Lowell and upper part of the Tinaja beds. The Ray Water Company reportedly serves from 850 to 900 connections from these wells. The City of Tucson has no active municipal wells within one mile of Julian Wash between Swan Road and the Tucson Diversion Channel. However, the City has four active municipal wells for domestic supply within one-half mile of Julian Wash between the diversion channel and the I-19 interchange (Table 3). These wells (B-32, B-35, B-76, and B-83) range in depth from 530 to 885 feet and also tap the Fort Lowell Formation and Tinaja beds. Total

TABLE 2--DATA FOR RAY WATER COMPANY WELLS
(T15S/R14E)

State Well No.	Date Drilled	Method	Total Depth (Feet)	Depth Casing (Feet)	Diam. Casing (Inches)	Perforations (Feet)
4dbb (No. 4)	-	-	-	-	-	-
10aba (No. 2)	9/69	Cable Tool	563	563	12	200-563
10acd (No. 6)	9/73	Cable Tool	600	500	12	-
10bbb (No. 3)	9/59	Cable Tool	505	505	-	-
10dbb (No. 5)	9/73	Cable Tool	500	500	12	180-500

Data from Arizona State Land Dept. files. Well locations shown on Figure 2.

TABLE 3--DATA FOR CITY OF TUCSON WELLS NEAR JULIAN WASH

State Well No.	Date Drilled	Method	Total Depth (Feet)	Depth Casing (Feet)	Diam. Casing (Inches)	Perforations (Feet)
(D-14-13)25cca(B-32)	10/46,1/66	Cable Tool	547	547	12, 10	250-547
(D-14-13)36abc(B-83)	1939, 1974	Cable Tool	530	529	16, 12	-
(D-14-14)29acd(C-8)	4/53	Cable Tool	490	478	16	130-458
(D-14-14)29cbc(B-76)	-	Cable Tool	885	885	16, 10	186-885
(D-14-14)30bbd(B-35)	8/50, 2/65	Cable Tool	861	861	12, 10	458-861

Data from City of Tucson, Water Department files. Well locations shown on Figure 2.

pumpage from wells B-32, B-35, B-76, and B-83 was 1,030 acre-feet in 1974. The City has one active municipal well for domestic supply (SS-13) within one-half mile and upstream of the spill point of Julian Wash into the Santa Cruz River. The City has three active municipal wells (SS-16, SS-18, and SS-19) within one-half mile of the Santa Cruz River, downstream of Julian Wash, and upstream of the Congress Street Bridge. City wells along the Santa Cruz River are part of the Southside Well Field, are generally less than 300 feet deep, and have shallow perforations (Table 4). Such wells primarily tap groundwater in the Fort Lowell Formation. Virtually all of the groundwater pumped near the lower part of Julian Wash is for domestic use. Total pumpage from wells SS-13, SS-16, SS-18, and SS-19 was 1,500 acre-feet in 1974.

Groundwater Quality

Water pumped from the "shallow" wells at TG&E is a sodium bicarbonate-sulfate type, is hard, and total dissolved solids contents are about 400 mg/l (Table 5). Fluoride contents are less than 1.0 mg/l and the water is apparently of escellent chemical quality for domestic use, except for the hardness. Water pumped from the deep wells at TG&E is a sodium sulfate type, is soft, and contains total dissolved solids ranging from 500 to 700 mg/l (Table 6). Fluoride contents are very high, ranging from 3 to 11 mg/l, and the water is warm. Fluoride contents greatly exceed the maximum contaminant level of 1.4 mg/l established by the U.S. Environmental Protection Agency (1976) for community water systems.

TABLE 4--DATA FOR CITY OF TUCSON WELLS
NEAR SANTA CRUZ RIVER

State Well No.	Date Drilled	Method	Total Depth (Feet)	Depth Casing (Feet)	Diam. Casing (Inches)	Perforations (Feet)
(D-14-13)13cac(SS-16)	3/46	Cable Tool	274	200	16	50-190
(D-14-13)23abd(SS-19)	8/50	Cable Tool	274	192	-	25-180
(D-14-13)23bad(SS-18)	7/50	Cable Tool	202	180	-	22-160
(D-14-13)26caa(SS-13)	1930	Cable Tool	282	-	-	-
(D-14-13)35bab(SS-24)	4/66	Cable Tool	350	328	12	87-328

Data from City of Tucson, Water Department files. Well locations shown on Figure 2.

TABLE 5--CHEMICAL ANALYSES FOR WATER FROM TG&E SHALLOW WELLS (T15S/R14E)

State No.	3aba	3acb	3acd	3bbb		3bdb	
Local No.	3A	2A	8	4		1	
Calcium	37	44	38	49	44	41	40
Magnesium	4	6	5	7	6	5	5
Sodium	64	54	61	54	56	38	59
Potassium	-	-	-	-	-	-	-
Carbonate	-	-	-	-	0	-	0
Bicarbonate	138	146	140	146	138	144	137
Sulfate	105	110	110	120	124	115	115
Chloride	10	11	10	13	10	12	12
Nitrate	-	-	-	-	4	-	4
Silica	29	30	29	31	-	30	-
Boron	-	-	-	-	0.09	-	0.09
Fluoride	0.7	0.7	0.8	0.3	0.3	0.4	0.3
pH	8.0	7.9	8.0	7.8	8.1	7.9	7.9
Electrical Conductivity (micromhos/cm @ 25°C)	500	515	500	535	480	515	460
Total Dissolved Solids	-	-	-	-	370	-	363
Total Hardness ($CaCO_3$)	108	136	114	150	135	124	123
Temperature (°F)	-	-	-	-	84	-	86
Date	8/8/75	7/29/75	8/18/75	7/30/75	10/13/77	7/29/75	10/13/77
Lab	Calgon	Calgon	Calgon	Calgon	BC Labs	Calgon	BC Labs
Well Depth (feet)	1,000	1,008	1,044	868		1,120	

Values in mg/l unless noted otherwise. Well locations shown on Figure 2. Calgon analyses by Water Management Division, Calgon Laboratories, Pittsburg, Pennsylvania, from TG&E files. Analyses by BC Laboratories, Bakersfield, California were collected during this investigation. Hardness values for 1977 analyses are calculated.

TABLE 6--CHEMICAL ANALYSES FOR WATER FROM TG&E DEEP WELLS (T15S/R14E)

State No.	2cac	3dad	
Local No.	5	6	
Calcium	4	3	3
Magnesium	<1	<1	<1
Sodium	200	160	152
Potassium	-	-	-
Carbonate	16	20	19
Bicarbonate	61	75	52
Sulfate	275	175	199
Chloride	42	31	39
Nitrate	-	-	4
Silica	29	35	-
Boron	-	-	0.20
Fluoride	11.0	3.5	4.2
pH	9.1	9.2	9.5
Electrical Conductivity (micromhos/cm @ 25°C)	980	725	650
Total Dissolved Solids	-	-	503
Total Hardness ($CaCO_3$)	12	7	8
Temperature (°F)	-	-	133
Date	7/12/75	8/12/75	10/13/77
Lab	Calgon	Calgon	BC Labs
Well Depth (feet)	2,500	2,505	

Values in mg/l unless noted otherwise. Well locations shown on Figure 2. Calgon analyses by Water Management Division, Calgon Laboratories, Pittsburg, Pennsylvania, from TG&E files. Analyses by BC Laboratories, Bakersfield, California were collected during this investigation. Hardness value for 1977 analysis is calculated.

Water pumped from Ray Water Company wells (Table 7) is a calcium sulfate type, is very hard, and contains total dissolved solids ranging from 425 to about 540 mg/l. Fluoride contents are less than 0.4 mg/l and the water is of excellent chemical quality for domestic use, except for the high hardness. Analyses by the Arizona Department of Health Services for arsenic, silver, chromium, cadmium, lead, selenium, and mercury in 1975 indicated that levels of these constituents were below the maximum contaminant levels established by the U.S. Environmental Protection Agency. Comparison of these results with those for the "shallow" TG&E wells indicates that water pumped from Ray Water Company wells is harder, has a higher content of total dissolved solids, and contains more sulfate than water from TG&E wells. Water from the Ray Water Company wells is more representative of the chemical quality of shallow groundwater, as these wells are 600 feet deep or less, whereas TG&E "shallow" wells are about 1,000 feet deep.

Water pumped from City of Tucson wells along Julian Wash is usually of the sodium bicarbonate-sulfate type, ranges from moderately hard to very hard, and total dissolved solids contents range from 300 to 500 mg/l (Table 8). Except for hardness and fluoride content, the water is of excellent chemical quality for domestic use. Fluoride contents exceed the limit of 1.4 mg/l and hardness is very high in water from some wells. Water pumped from

TABLE 7--CHEMICAL ANALYSES FOR WATER FROM RAY WATER COMPANY WELLS (T15S/R14E)

State No.	4dbb	10aba	10acd	10bbb	10dbb
Local No.	4	2	6	3	5
Calcium	87	81	84	104	86
Magnesium	12	14	23	12	18
Sodium	46	39	47	40	48
Carbonate	0	0	0	0	0
Bicarbonate	171	173	168	166	180
Sulfate	170	174	190	184	190
Chloride	20	24	16	30	20
Nitrate	3	5	10	4	5
Iron	0.20	0.12	0.12	0.13	0.09
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	0.2	0.2	0.2	0.2	0.3
pH	8.0	8.0	-	8.0	8.2
Electrical Conductivity (micromhos /cm @ 25°C)	665	695	640	735	645
Total Dissolved Solids	425	435	490	475	539
Total Hardness ($CaCO_3$)	270	278	304	292	292
Date	1/30/75	1/30/75	5/15/75	1/30/75	5/15/75
Well Depth (feet)	-	563	600	505	500

Analyses by Arizona Department of Health Services Lab, in mg/l unless noted otherwise.
Well locations shown on Figure 2.

TABLE 8--CHEMICAL ANALYSES FOR WATER FROM CITY OF TUCSON WELLS NEAR JULIAN WASH

State No.	T14S/R13E		T14S/R14E		
Local No.	-25cca B-32	-36abc B-83	29acd C-8	29cbc B-76	30bbd B-35
Calcium	22	22	40	43	78
Magnesium	4	5	14	4	16
Sodium	100	86	68	120	45
Carbonate	5	0	0	0	0
Bicarbonate	151	120	146	127	166
Sulfate	105	98	104	180	188
Chloride	16	18	13	47	21
Nitrate	2	4	<1	<1	4
Iron	-	<0.05	0.08	0.09	0.89
Manganese	-	<0.05	<0.05	<0.05	<0.05
Fluoride	1.8	1.4	0.3	0.9	0.2
pH	8.1	8.3	8.2	8.2	7.5
Electrical Conductivity (micromhos/cm @ 25°C)	570	500	477	715	633
Total Dissolved Solids	407	370	330	482	474
Total Hardness ($CaCO_3$)	70	78	158	124	264
Date	12/6/64	7/1/75	5/29/75	5/29/75	2/2/77
Well Depth (feet)	547	530	490	885	861
Lab	U of A	State	State	State	State

U of A analyses by Department of Agricultural Chemistry and Soils, University of Arizona, Tucson. State analyses by Arizona Department of Health Services Lab. Values in mg/l unless noted otherwise. Well locations shown on Figure 2.

City of Tucson wells along the Santa Cruz River between Julian Wash and the Congress Street Bridge is usually a sodium bicarbonate-sulfate type, ranges from soft to very hard, and total dissolved solids contents range from 400 to 700 mg/l (Table 9). Fluoride contents greatly exceed the limit of 1.4 mg/l and hardness is very high in water from some wells. The water is of excellent chemical quality for domestic use except for hardness and fluoride content. Trace elements analyzed by The Arizona Department of Health Services for these City of Tucson wells were also below the maximum contaminant levels.

PROPOSED WASTEWATER DISCHARGE

It is proposed to discharge 742,000 gallons per day, or 830 acre-feet per year, of cooling tower blowdown wastewater into Julian Wash. The water would be conveyed from the plant into an arroyo and through culverts beneath the Southern Pacific Railroad and Interstate I-10 to Julian Wash just above the Alvernon Way crossing (Figure 1). The blowdown wastewater is derived from four cooling tower units. Water is supplied from wells and is concentrated about five times during its use in the cooling process. Sulfuric acid is added to neutralize the alkalinity of the well water, chlorine is added for algae control, and hexametaphosphates are added to prevent scale formation and inhibit corrosion.

Chemical analyses are available for composite samples of the wastewater taken in 1967 and 1976. Water samples from the four

TABLE 9--CHEMICAL ANALYSES FOR WATER FROM CITY OF TUCSON WELLS NEAR SANTA CRUZ RIVER (T14S/R13E)

State No.	13cac	23abd	23bad	26cad	35bab
Local No.	SS-16	SS-19	SS-18	SS-13	SS-24
Calcium	48	3	106	20	55
Magnesium	4	2	15	2	11
Sodium	163	127	88	96	67
Carbonate	0	7	0	1	0
Bicarbonate	149	159	300	185	212
Sulfate	235	116	218	83	98
Chloride	60	18	28	13	15
Nitrate	16	5	7	4	3
Iron	0.07	<0.05	<0.05	<0.05	<0.05
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	3.4	4.4	0.8	0.8	0.9
pH	7.8	9.2	7.7	-	-
Electrical Conductivity (micromhos/cm @ 25°C)	1,010	625	980	-	570
Total Dissolved Solids	689	408	648	393	394
Total Hardness ($CaCO_3$)	136	16	326	60	182
Date	4/8/76	5/26/76	5/25/76	10/23/75	11/12/75
Well Depth (feet)	274	274	202	282	350

Analyses by Arizona Department of Health Services Lab. Values in mg/l unless noted otherwise.
Well locations shown on Figure 2.

cooling tower units were collected in October 1977, temperatures and electrical conductivities were measured, and two samples selected for chemical analysis (Table 10). The wastewater is of the sodium sulfate type, is very hard, and fluoride contents are very high, exceeding 7 mg/l in some cases. It should be noted that because of the relatively high contents of calcium sulfate, the total dissolved solids values reported for residue at 180°C may include several hundred mg/l of water associated with gypsum. Ignition at 600°F would provide a more suitable indication of actual total dissolved solids content. Total dissolved solids content is estimated to average about 2,000 mg/l under present conditions. The trace element composition of the wastewater was not determined during this investigation.

IMPACTS

During periods of no natural streamflow, the proposed discharge would enter Julian Wash near Alvernon Way and flow along a two and one-half mile reach of unlined channel. Evaluation of available data on the lithology and hydraulic characteristics of shallow materials in the vicinity indicates that some infiltration can be expected. However, significant amounts of wastewater are expected to reach the Tucson Diversion Channel, at which point the Julian Wash Channel is lined. The lining extends to the floodplain of the Santa Cruz River; thus most of the water reaching the lined portion will be conveyed to the Santa Cruz River. During periods of storm runoff, flow may be present in Julian Wash and the Tucson Diversion Channel, and the wastewater could be substantially diluted.

TABLE 10--CHEMICAL ANALYSES OF COOLING TOWER BLOWDOWN

	Composite 9/67	Composite 4/76	Tower No. 2 10/13/77	Tower No. 3 10/13/77
Calcium	161	200	255	225
Magnesium	21	-	36	31
Sodium	440	-	335	501
Potassium	12	-	-	-
Carbonate	-	-	0	0
Bicarbonate	28	53	18	29
Sulfate	1,167	1,375	1,311	1,435
Chloride	116	90	95	188
Nitrate	6	-	23	19
Silica	59	181	-	-
Boron	0.6	-	0.3	0.5
Fluoride	7.1	-	2.6	6.0
pH	7.8	7.6	7.4	7.5
Electrical Conductivity (micromhos/cm @ 25°C)	-	-	3,000	3,300
Total Dissolved Solids	2,022	1,925	2,447	2,697
Total Hardness ($CaCO_3$)	489	600	785	690
Temperature (°F)	82	-	72	77

Source: 1967 and 1976 analyses from Santa Cruz River Park Master Plan (City of Tucson, 1977). 1977 analyses by BC Laboratories, Bakersfield, California, were collected during this investigation. Values in mg/l unless noted otherwise. 1977 values for total dissolved solids are residue at 180°C. Hardness values for the 1967 and 1977 analyses are calculated.

However, these flow periods are of short duration. Water flowing in the Santa Cruz River could also substantially dilute the wastewater; however, as previously noted, natural flows are also of short duration. Thus, the normal situation is for the water to be discharged into dry channels.

Data on infiltration of streamflow in the Tucson Basin has primarily been developed for the main channels under natural flow conditions. Little quantitative data are available on infiltration of streamflow along tributaries of the Santa Cruz River, such as Julian Wash. However, the presence of caliche in the shallow alluvium and the lack of deep channel entrenchment through these layers suggest that infiltration along Julian Wash would be limited. The proposed discharge is several hundred acre-feet per year less than the estimated existing average annual runoff in Julian Wash. Information on subsurface lithology discussed previously indicates that the shallow materials along the unlined part of Julian Wash should not be considered impermeable. This is primarily because the caliche is not of the dense, compact type, is not continuous, and is relatively thin. The exact infiltration rate in this reach can only be determined by measurement of flow during actual wastewater discharge to Julian Wash.

Beneath the upper half of the unlined reach below the proposed discharge, the direction of groundwater movement is to the northeast, toward the TG&E well field. Pumpage in this area is estimated to exceed 4,700 acre-feet per year. Infiltrated

wastewater in this area can largely be expected to enter the TG&E well field where it would be substantially diluted. Beneath the lower half of the unlined reach below the proposed discharge, the direction of groundwater movement is likely to the north. A lack of water-level measurements in this area limits the interpretation that can be made. Infiltrated wastewater in this area can be expected to eventually enter the City of Tucson Interior well field.

The channel of the Santa Cruz River has entrenched below most of the caliche layers present beneath nearby terraces in the basin, thus infiltration of streamflow is enhanced. Burkham (1970) reported on infiltration rates from streamflow in the main channels of the Tucson Basin. The portion of the Santa Cruz River below Julian Wash and above the Congress Street Bridge is included in Reach 1 of his report. Reach 1 extends from Continental to the Congress Street Bridge, a distance of 28.5 miles. Burkham (1970) reported that alluvium beneath the main channels ranges in size from clay to boulders. During period of no flow, the alluvium along the channel beds is normally stratified, with clay and silt on the surface and clay, silt, and sand interbedded with gravel below the surface.

Burkham (1970) reported that infiltrated water is depleted as it passes through the unsaturated zone and brings the zone to field capacity. The amount of moisture necessary to bring the zone to field capacity is a direct result of the amount of evapotranspiration that occurs between runoff events. He reported that

about 90 percent of the average annual infiltrated water probably reaches the water table. Burkham (1970) developed equations to describe infiltration of streamflow in Reach 1 for natural flow conditions. The average annual infiltration in Reach 1 was 320 acre-feet per river mile.

Data from Burkham's study cannot be directly applied to infiltration of wastewater in the Santa Cruz River channel below Julian Wash for several reasons. First, it cannot be assumed that the subsurface materials beneath the channel in this reach are similar to the average of those in Reach 1. Second, the wastewater flow of about 1.1 cfs (if no losses occurred above the Santa Cruz River) is much less than the 10 cfs which was the minimum flow considered in his analysis. Third, the wastewater discharge would be rather uniform throughout the year and not concentrated during several weeks of flow as are the natural flows. Fourth, the sediment content of the wastewater is much less than that of natural flows. Lastly, and most importantly, gravel processing operations in the floodplain of the Santa Cruz River above Julian Wash can greatly affect infiltration rates due to sediment discharge.

The City of Tucson (1977) reported on flows from the gravel processing operation south of Valencia Road. They stated that infiltration of about 1 cfs of wastewater occurred within several miles of the plant. However, the infiltration at any specific time depends on the character of fine-grained materials deposited on the channel bottom. Flow is reported to extend downstream a much

greater distance when a well-developed low permeability layer is present. Immediately after a storm runoff event, this layer may be absent and substantial infiltration can occur over a short distance. Unfortunately, this phenomenon has not been quantitatively documented. Also, the future operation and character of the waste discharge is uncertain due to possible changes in regulations and other factors. The exact infiltration rate in this area can only be determined by measurements of flow during actual wastewater discharge to Julian Wash. However, for purposes of this analysis, it is reasonable to assume that most of any wastewater from the proposed discharge that reaches the mouth of Julian Wash will infiltrate from the Santa Cruz River channel within a distance of several miles from the mouth.

Groundwater beneath the Santa Cruz River near Julian Wash moves northerly. Wastewater infiltrated in this area can be expected to enter the City of Tucson Southside well field. Pumpage in this area is estimated to exceed 1,500 acre-feet per year.

The impact of the proposed discharge is to be assessed for total dissolved solids contents of 500 mg/l, 1,000 mg/l, and 2,500 mg/l in the wastewater. Furthermore, it is assumed that the proposed discharge has a chemical quality similar to that of the present blowdown. An important consideration in this analysis is that the discharge is in an area of heavy pumping. Thus, the impact cannot be addressed in the same manner as that for a situation where little or no pumping is occurring. Each year,

large amounts of water are pumped from beneath the urban part of the Tucson Basin. Large amounts of this pumped water are then exported through sewers and leave the Tucson Basin as surface water flow in the Santa Cruz River below Tucson. Also, salts in the proposed wastewater discharge originate from groundwater in the basin, but could be re-distributed in a different manner as a result of the discharge. Furthermore, the larger the area over which the wastewater is infiltrated, the less the resulting impact on groundwater will be. This is due to the greater dilution provided by the greater volume of groundwater in storage beneath the larger area.

Water Quality Criteria

Constituents in the wastewater that occur at sufficient concentrations to present a potential threat to groundwater quality include: total dissolved solids, sulfate, fluoride, and hardness. Of these constituents, only fluoride has been assigned a maximum contaminant level for community water systems by the U.S. Environmental Protection Agency (1976) as part of the National Interim Primary Drinking Water Regulations. The level for fluoride depends on the annual average of the maximum daily air temperatures at the location. Sellers and Hill (1974) give the mean value for the period 1948-70 at Tucson Airport as 82°F, thus the maximum contaminant level for Tucson is 1.4 mg/l.

Certain constituents are not directly related to the safety of drinking water, but rather to the esthetic quality. Such constituents are to be listed in the Secondary Drinking Water

Regulations. Recommended levels in the 1962 U.S. Public Health Service drinking water limits included 250 mg/l for sulfate content and 500 mg/l for total dissolved solids content. Water with a hardness as calcium carbonate less than 60 mg/l is classified as soft, between 60 and 120 mg/l as moderately hard, between 120 and 180 mg/l as hard, and exceeding 180 mg/l as very hard (Laney, 1972).

Low Salinity Discharge

The discharge of 500 mg/l total dissolved solids wastewater would have little or no measurable impact on groundwater quality in the Tucson Basin. This water would have a total dissolved solids content about double that projected for storm runoff in Julian Wash. However, the total dissolved solids content is only slightly greater than that in water pumped from "shallow" wells at TG&E, wells at the Ray Water Company, and City of Tucson wells along Julian Wash. The salinity of 500 mg/l is in the range of that of water pumped from many City wells along the Santa Cruz River below Julian Wash.

Moderate Salinity Discharge

The discharge of 1,000 mg/l total dissolved solids wastewater would have some impact on groundwater quality in the basin. This salinity is generally about double that of shallow groundwater in the area. Wells that could be significantly affected and be grouped into two areas: (1) along the unlined portion of Julian Wash, and (2) along the Santa Cruz River near and below Julian Wash. If significant infiltration of the wastewater occurs

in either area, then an increase in groundwater salinity will occur.

The primary municipal well that could be affected by this discharge is Ray Water Company Well No. 4, which is within 1,000 feet of Julian Wash and downstream of the proposed discharge. Many of the Ray Water Company wells have shallow perforations which may extend above the water table and such wells are especially vulnerable to contamination. A mitigating factor is that the wells are hydraulically upgradient from the proposed discharge point and Julian Wash. However, the cone of depression from Well No. 4 could intercept percolated wastewater beneath Julian Wash. Also, the presence of perching layers above the water table could allow lateral movement of infiltrated wastewater above the water table and toward Well No. 4. TG&E wells No. 1 and 4 are hydraulically downgradient of the proposed discharge point and would likely be affected if infiltration of wastewater occurs. Both of these wells are perforated above the water level and are thus especially vulnerable to contamination. TG&E wells No. 2A and 3A could also be affected, but to a lesser degree. The greatest effect would probably be an increase in total dissolved solids content of several hundred mg/l. The degradation would be mitigated because the wells pump water from strata at a number of different depths, and water comes from a number of directions toward the wells. If little or no wastewater infiltration occurs in this reach, then no measurable impact on groundwater quality will result.

The primary wells that could be affected along the Santa Cruz River are City of Tucson Wells No. SS-13, SS-18, and SS-19. Although Well SS-13 is upstream of the diverted channel of Julian Wash, it is within one-half mile of the wash. The depression cone due to pumping of this well could extend beneath the point where water enters the Santa Cruz River floodplain from Julian Wash. Wells SS-18 and SS-19 are downstream and within one mile of the wash. The perforations of most of these wells extend significantly above the water table and they are especially susceptible to contamination. These wells are also usually less than 300 feet deep and the aquifer is relatively thin in this area. The greatest effect would probably be an increase in total dissolved solids content of several hundred mg/l. Mitigating factors include the high transmissivity, which enhances mixing, dilution by underflow beneath the floodplain of the Santa Cruz River, and percolation of natural streamflow and possibly other water in the channel.

High Salinity Discharge

The discharge of 2,500 mg/l total dissolved solids wastewater could have a significant impact on the quality of water pumped from some wells in the basin. This salinity is about five times that of groundwater in the area. Wells that could be affected can be grouped into three areas: (1) near TG&E and the Ray Water Company, (2) along the unlined part of Julian Wash, and (3) along the Santa Cruz River near and below Julian Wash. If significant infiltration of wastewater occurs in any of these areas, then an increase in groundwater salinity will occur.

The primary municipal well that could be affected near TG&E is Ray Water Company Well No. 4. The greatest effect would probably be an increase in total dissolved solids content of several hundred mg/l. Fluoride contents could also be increased somewhat. A substantial adverse impact is unlikely near the TG&E well field because of the substantial dilution that would occur. Even if all of the wastewater infiltrated in this area, its volume would be less than 20 percent of the annual pumpage (4,700 acre-feet) in the area. TG&E wells No. 1 and 4 would likely be affected if infiltration of wastewater occurs. TG&E wells No. 2A and 3A could also be affected, but to a lesser degree. If no wastewater infiltration occurs in this reach, then no measurable impact on groundwater quality will result. Wells along the lower part of Julian Wash should not be adversely impacted because the wash is lined in this reach. However, City Wells No. B-76 and C-8 are downgradient of the unlined portion of Julian Wash and could be affected. The greatest effect would probably be an increase in total dissolved solids content of several hundred mg/l. If no infiltration occurs in this reach, then no measurable impact will result.

Wells along the Santa Cruz River that could be significantly affected include City of Tucson SS-13, SS-18, SS-19, and SS-16. The greatest effect would probably be an increase in total dissolved solids content of 500 to 800 mg/l. Fluoride contents could also be increased by about 1 to 2 mg/l, but those in water from some of these wells already greatly exceed the maximum contaminant level. If all

of the wastewater infiltrated in this area, the volume of infiltrated wastewater could exceed 50 percent of the annual pumpage (1,500 acre-feet) for domestic use in the area. Because the aquifer is relatively thin in this area, because substantial infiltration of wastewater in this area is likely, and because these are nearby downgradient wells used for domestic purposes, this area is the most crucial of those potentially impacted by the proposed waste discharge.

Future Groundwater Use

Because of the poor aquifer conditions along the unlined part of Julian Wash downstream of the proposed discharge, it is unlikely that large-capacity wells will be developed in the future in this area. However, degradation of groundwater near the Ray Water Company and along the Santa Cruz River near and below Julian Wash could limit future locations of large-capacity wells used for domestic supply.

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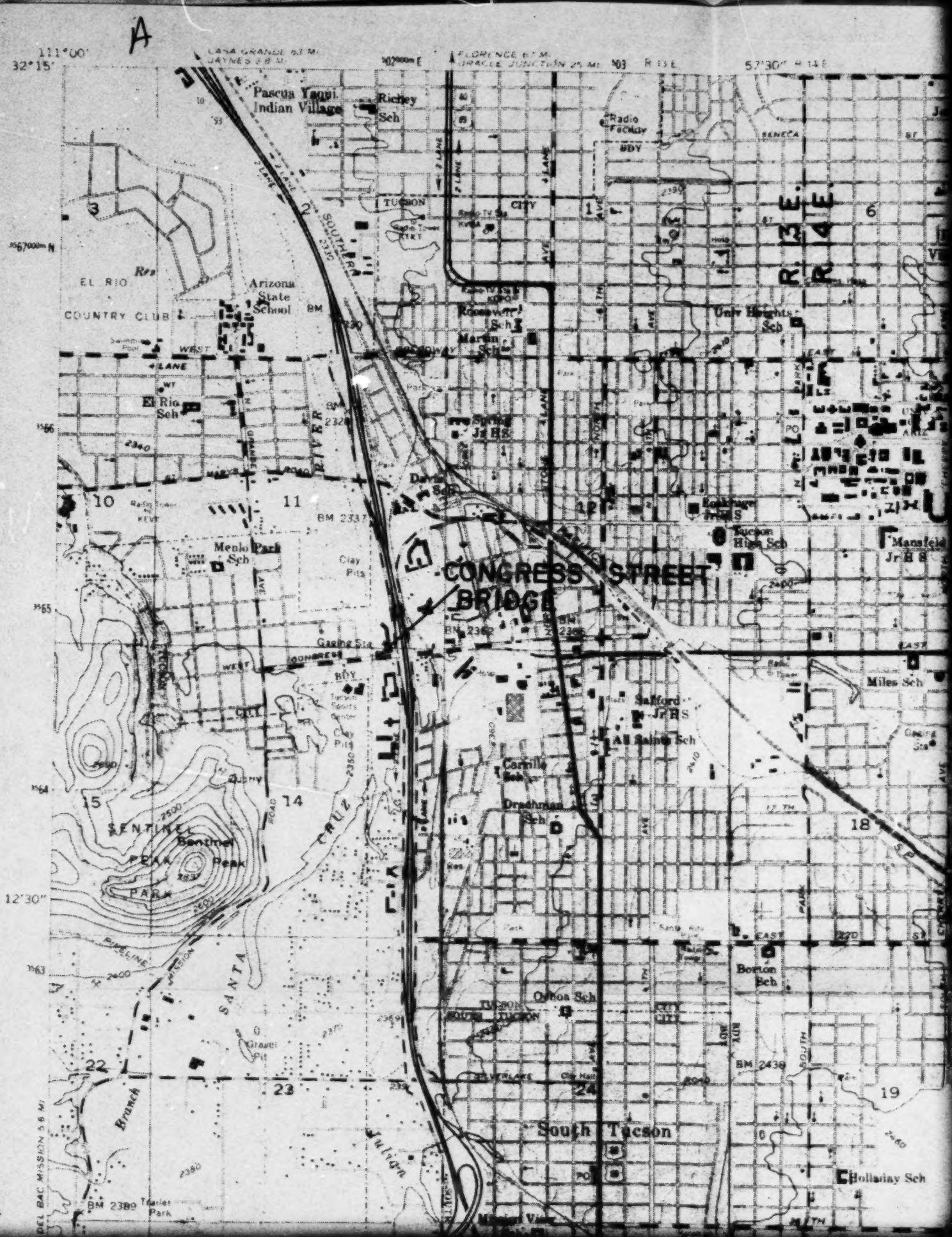
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Univ Heights Sch
El Rio Sch
Spring Jr HS
Davis Sch
CONGRESS STREET BRIDGE
Menlo Park Sch
Tucson High Sch
Mansfield Jr HS
Miles Sch
Safford Jr HS
All Saints Sch
Camille Sch
Dreshman Sch
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12'30"

1 B

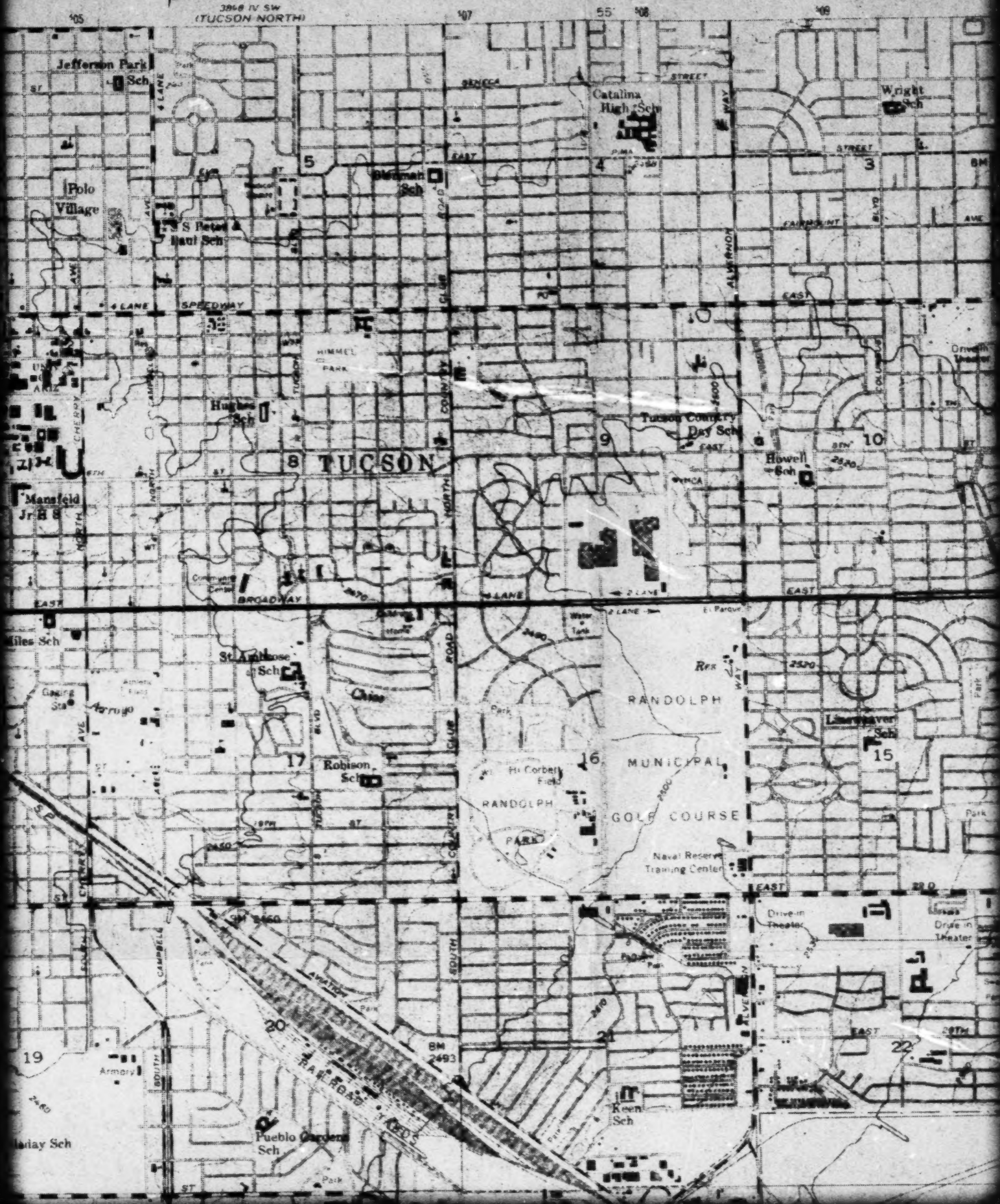
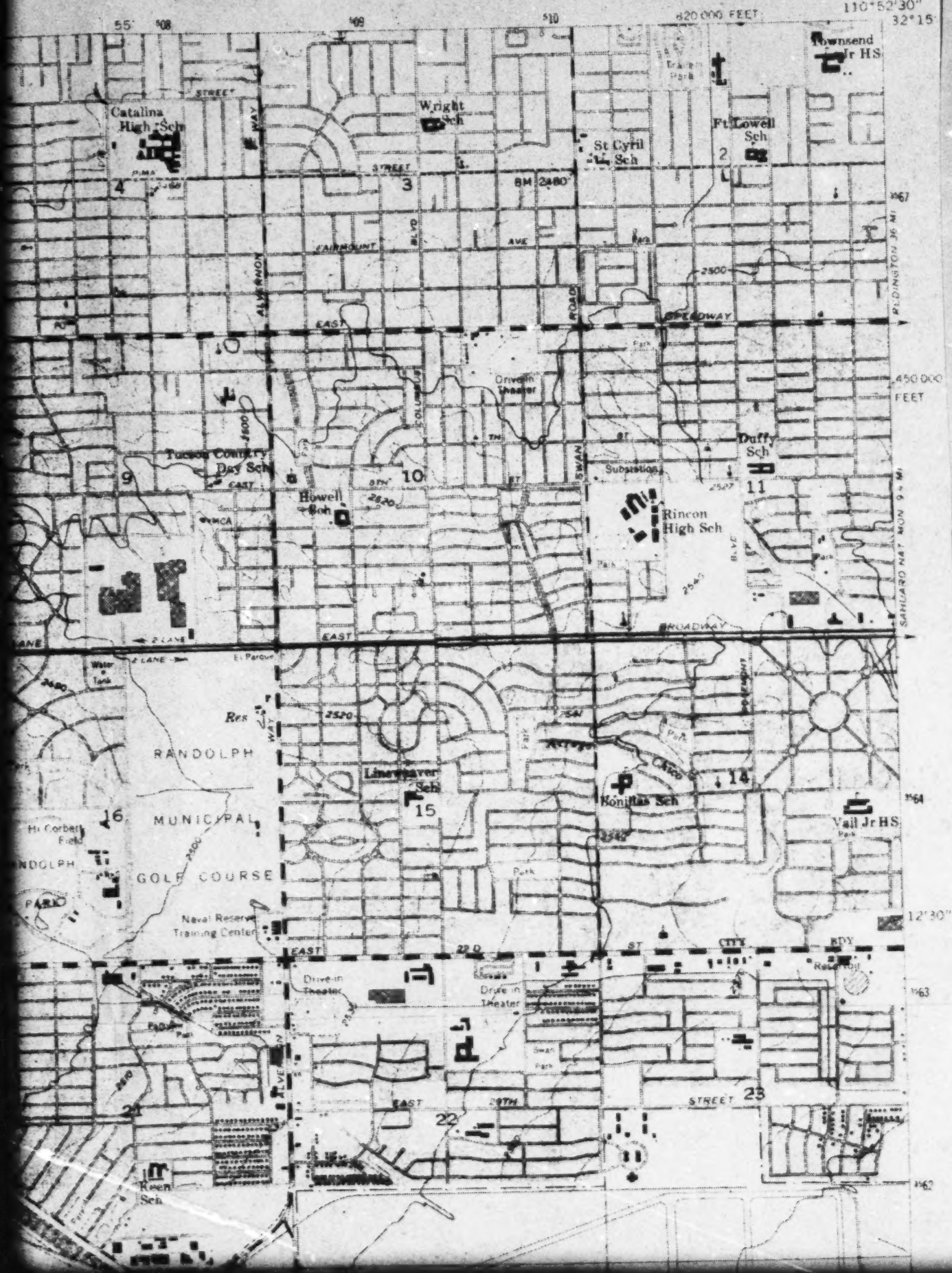

3868 IV SW
(TUCSON NORTH)
Jefferson Park Sch
Polo Village
S Peter & Paul Sch
Bleeman Sch
Catalina High Sch
Wright Sch
HIMMEL PARK
Hughes Sch
TUCSON
Tucson Country Day Sch
Howell Sch
Mansfield Jr H S
Miles Sch
St Ambrose Sch
Robison Sch
RANDOLPH MUNICIPAL GOLF COURSE
RANDOLPH PARK
H Corbett Field
Naval Reserve Training Center
Linenweber Sch
Drive-in Theater
Keen Sch
Pueblo Gardens Sch
RAILROAD
Armory
Gasoline Sta
Water Tank
BM 2493
SPEEDWAY
BROADWAY
4 LANE
2 LANE
NORTH
SOUTH
EAST
CAMPBELL AVE
CHERRY AVE
TUCSON BLVD
COUNTRY CLUB
ALVERNON WAY
FAIRMONT BLVD
DRACHMAN
STREET
ROAD
WAY
AVE
BLVD
PARK
5
4
3
8
9
10
17
16
15
19
20
21
22

FIGURE 1


110°52'30"
32°15'
620 000 FEET
450 000 FEET
Townsend Jr HS
Catalina High Sch
Wright Sch
St Cyril Sch
Ft Lowell Sch
BM 2480
Tucson Country Day Sch
Howell Sch
Drive-in Theater
Rincon High Sch
Duffy Sch
Substation
RANDOLPH
MUNICIPAL
GOLF COURSE
Naval Reserve Training Center
Linenweaver Sch
Koninas Sch
Vail Jr HS
Reen Sch
EAST BROADWAY
EAST 22ND STREET
SAHUARO NAT MON 9 MI
PLDNGTON 36 MI
CAIRMOUNT AVE
ALVERNON WAY
SWAN ROAD
COLUMBUS BLVD
PARK AVE
CAMPBELL AVE
SANTA RITA ROAD
RANDOLPH WAY
Arroyo
Park
Water Tank
YMCA
TH
CITY
RDY

D
DIVERTED
JULIAN WASH
LINED PART
OF JULIAN WASH
INTERSTATE
I-19
T. 14 S.
T. 15 S.
South Tacson
Holladay
Lynn Sch
Rose Sch
Van Buskirk Sch
Liberty Sch
St John's Sch
Gerard Heights Sch
HOSPITAL
COUNTY
FAIRGROUNDS
USGS
Recording Well
SANTA CRUZ VALLEY
SANTA CRUZ RIVER
Julian
Branch
West
Well
Rea
Wells
Gravel Pit
Trailer Park
DREXEL
IRVINGTON
SOUTHERN
FLETCHER
BM 2389
BM 2439
BM 2459
BM 2505
BM 2522
420 000 FEET
22
23
24
25
26
27
30
31
34
35
36
19
6
3
10

AJO WAY
DETENTION
BASIN.
TUCSON
DIVERSION
CHANNEL
INTERSTATE
I-10
TG & E
STATION
UNLINED
PART OF
JULIAN WASH
DETENTION
BASIN
LEVEE
AIRPORT
DOWNTOWN
Armory
Pueblo Gardens
Sch
Cavett
Sch
Polvo
Sunnyside
SOUTH LAWN
MEMORIAL
CEMETERY
DREXEL
RAILROAD
ROAD
CITY
AJO
WAY
BM 2493
BM 2475
BM 2486
BM 2570
BM 2553
2500
2530
2539
2550
2570
2573
2585
2594
19
20
21
22
27
28
29
30
31
32
33
34
5
6
4

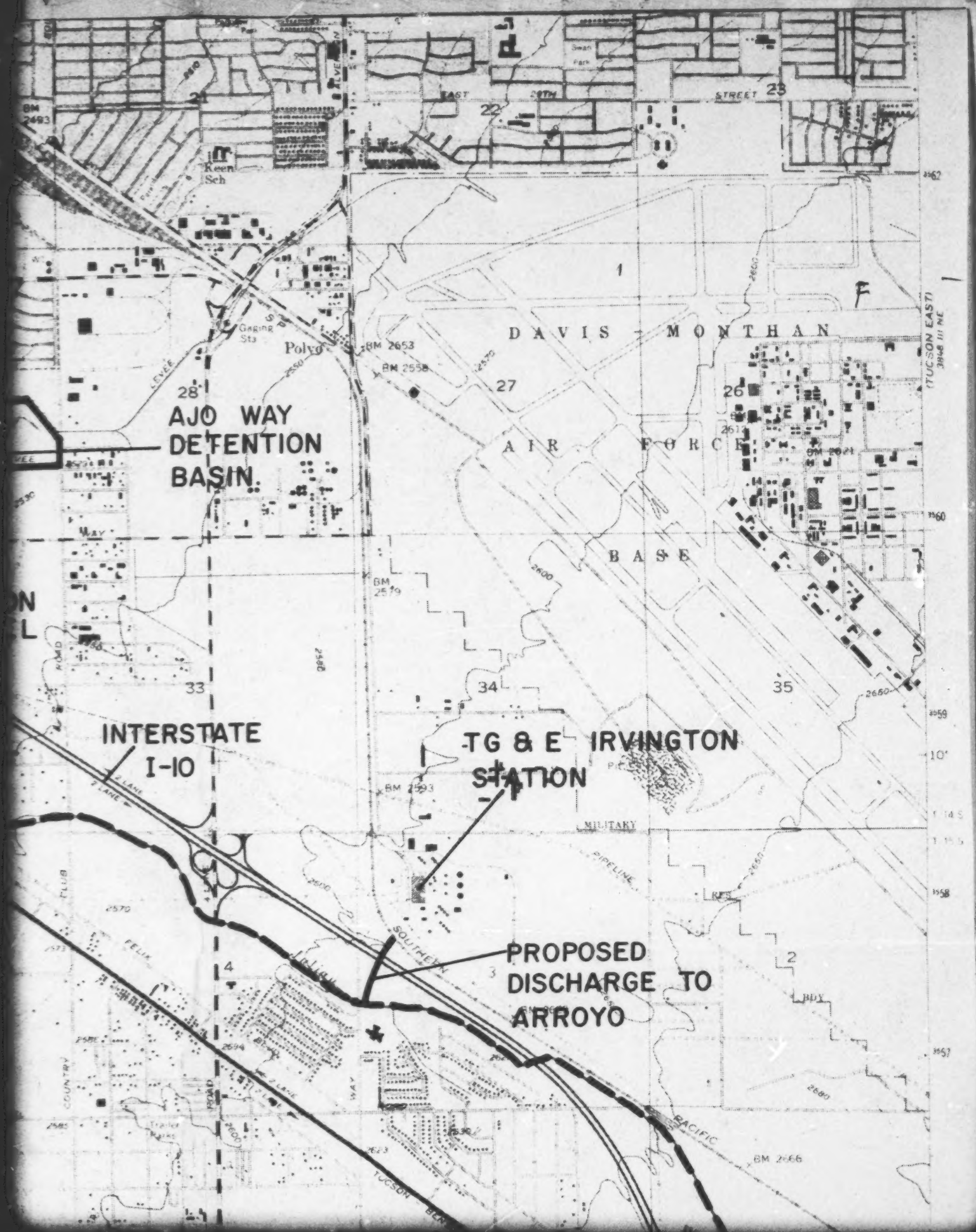

AJO WAY
DETENTION
BASIN
INTERSTATE
I-10
TG & E IRVINGTON
STATION
PROPOSED
DISCHARGE TO
ARROYO
DAVIS - MONTHAN
AIR FORCE
BASE

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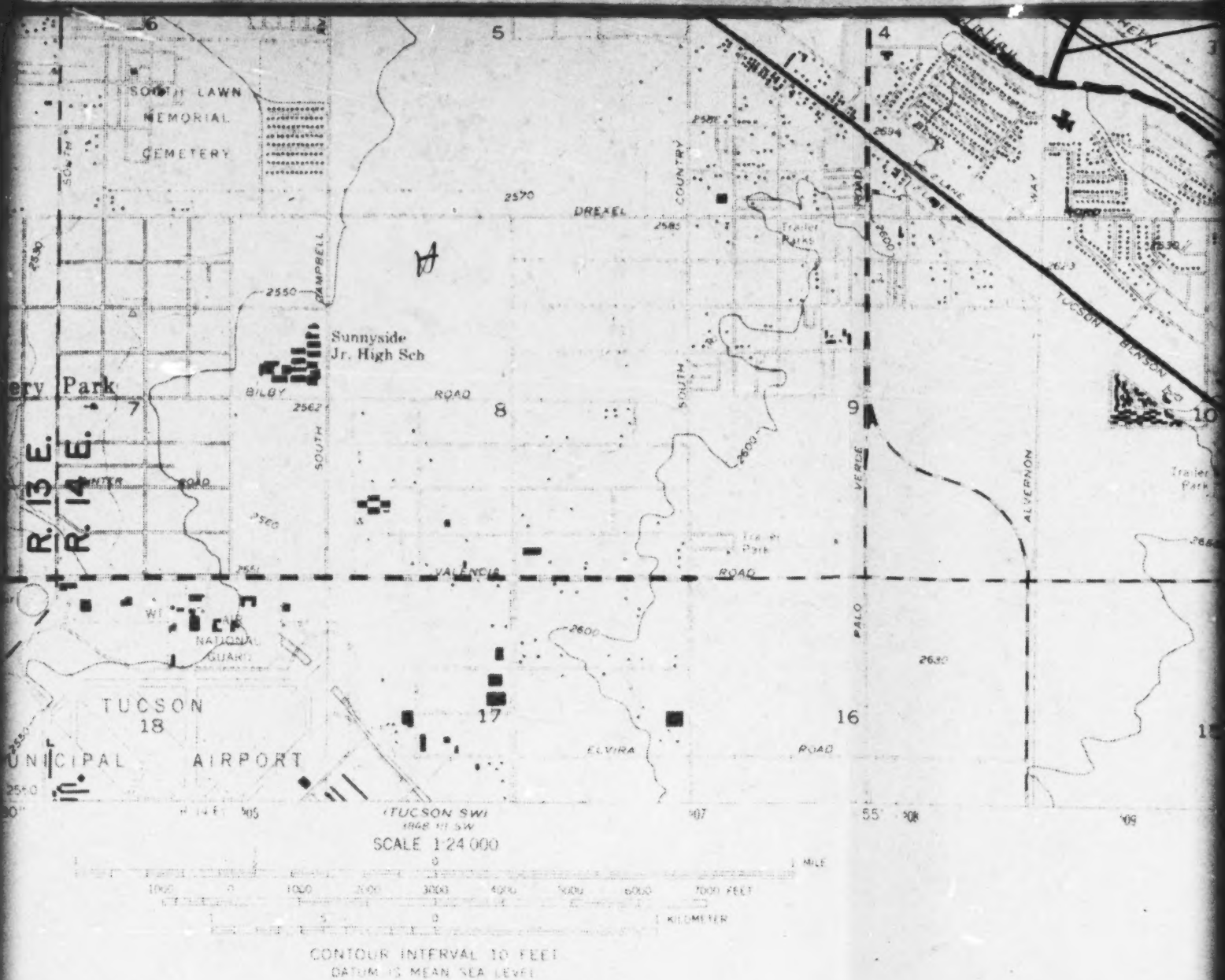
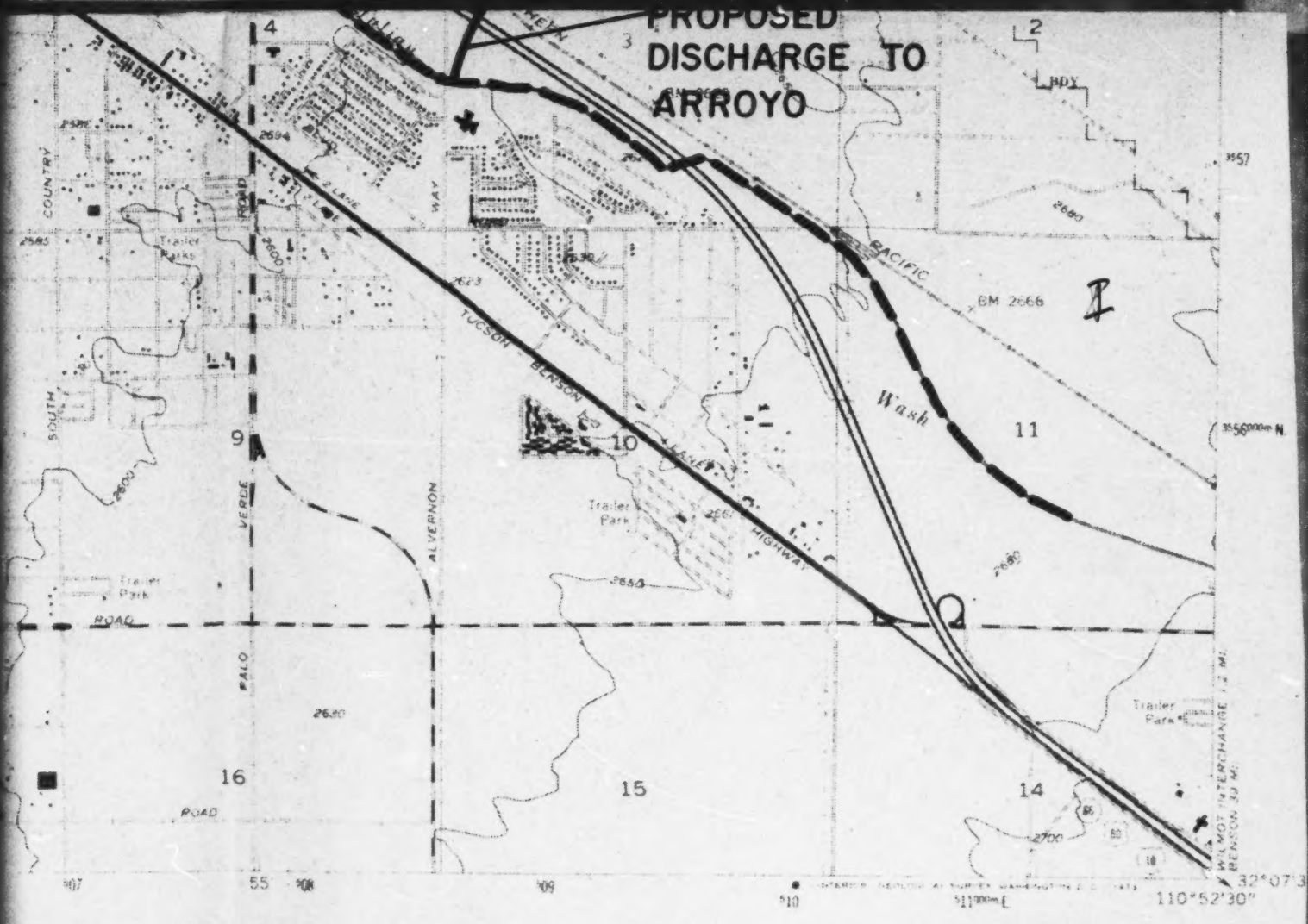
FIGURE

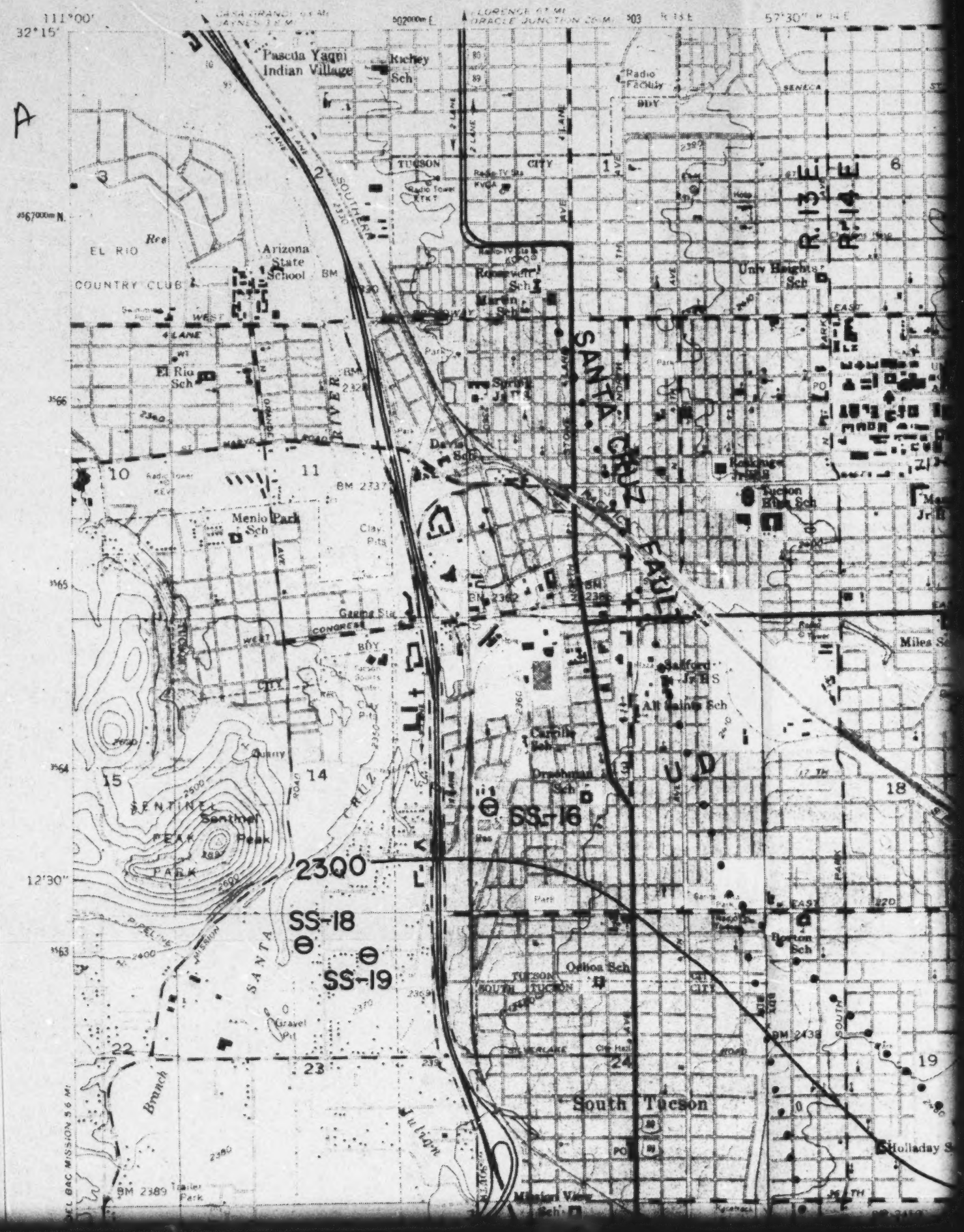


GURE 1.--LOCATION MAP OF PROJECT AREA.



REGISTERED GEOLOGIST
CERTIFICATE NO.
8019
Kenneth Dale Schmidt
DATE SIGNED 12-13-77
Arizona U. S. A.

PROJECT AREA.


A
111°00'
32°15'
Pascua Yaqui Indian Village
Richey Sch
Radio Facility
TUCSON
CITY
R. 13 E.
R. 14 E.
EL RIO COUNTRY CLUB
Arizona State School
Roosevelt Sch
Univ Heights Sch
SANTA CRUZ RIVER
El Rio Sch
Davis Sch
Menlo Park Sch
Clay Pits
Gamma Sta
Tucson High Sch
Miles Sch
Safford Jr HS
All Saints Sch
Carrillo Sch
Drachman Sch
SS-16
SENTINEL PEAK PARK
Sentinel Peak
2300
SS-18
SS-19
SANTA CRUZ
Gravel Pit
Quhoa Sch
Borton Sch
SOUTH TUCSON
South Tucson
Holladay Sch
Mission View Sch
Trailer Park
BM 2389
BM 2438
BM 2737
12'30"

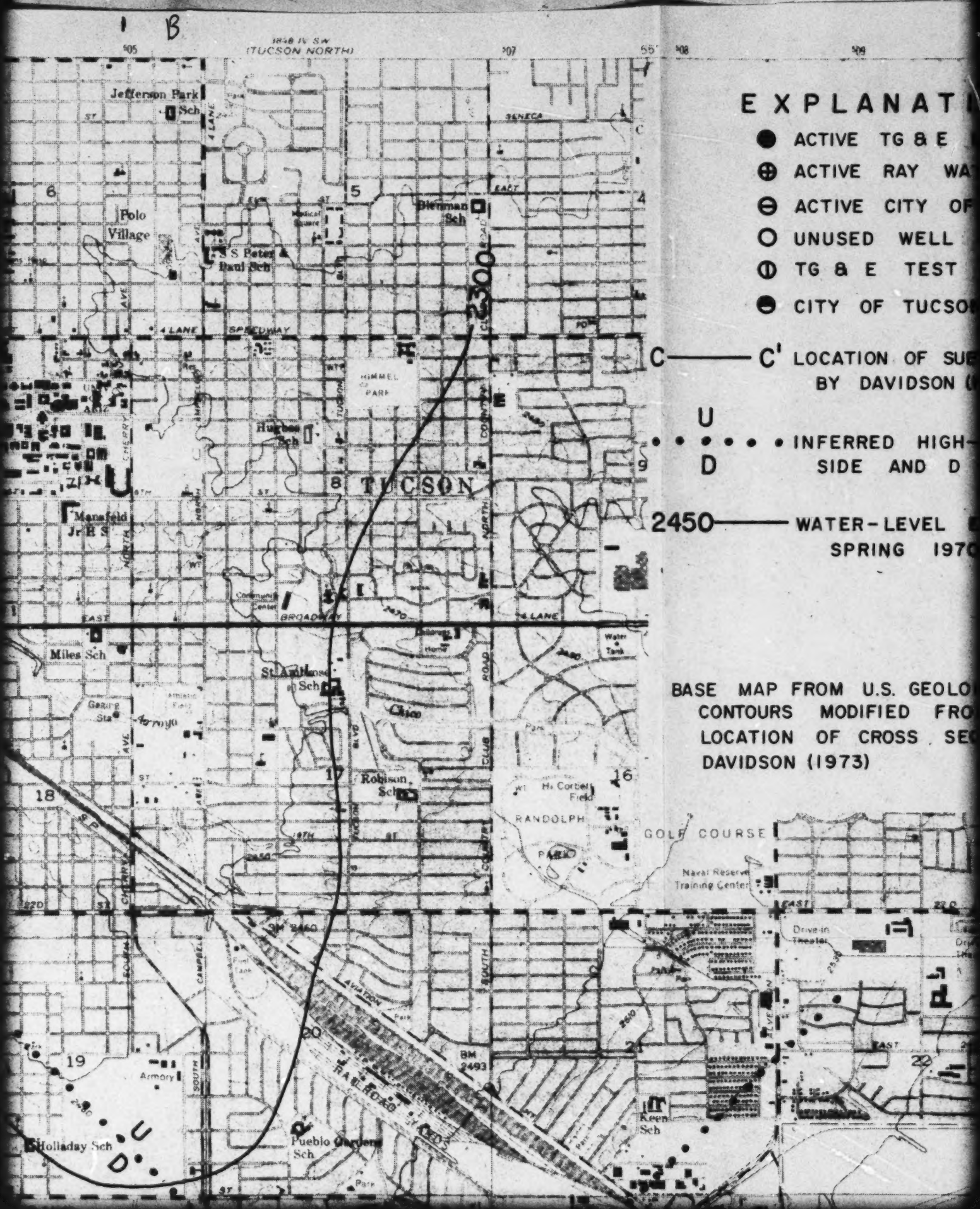
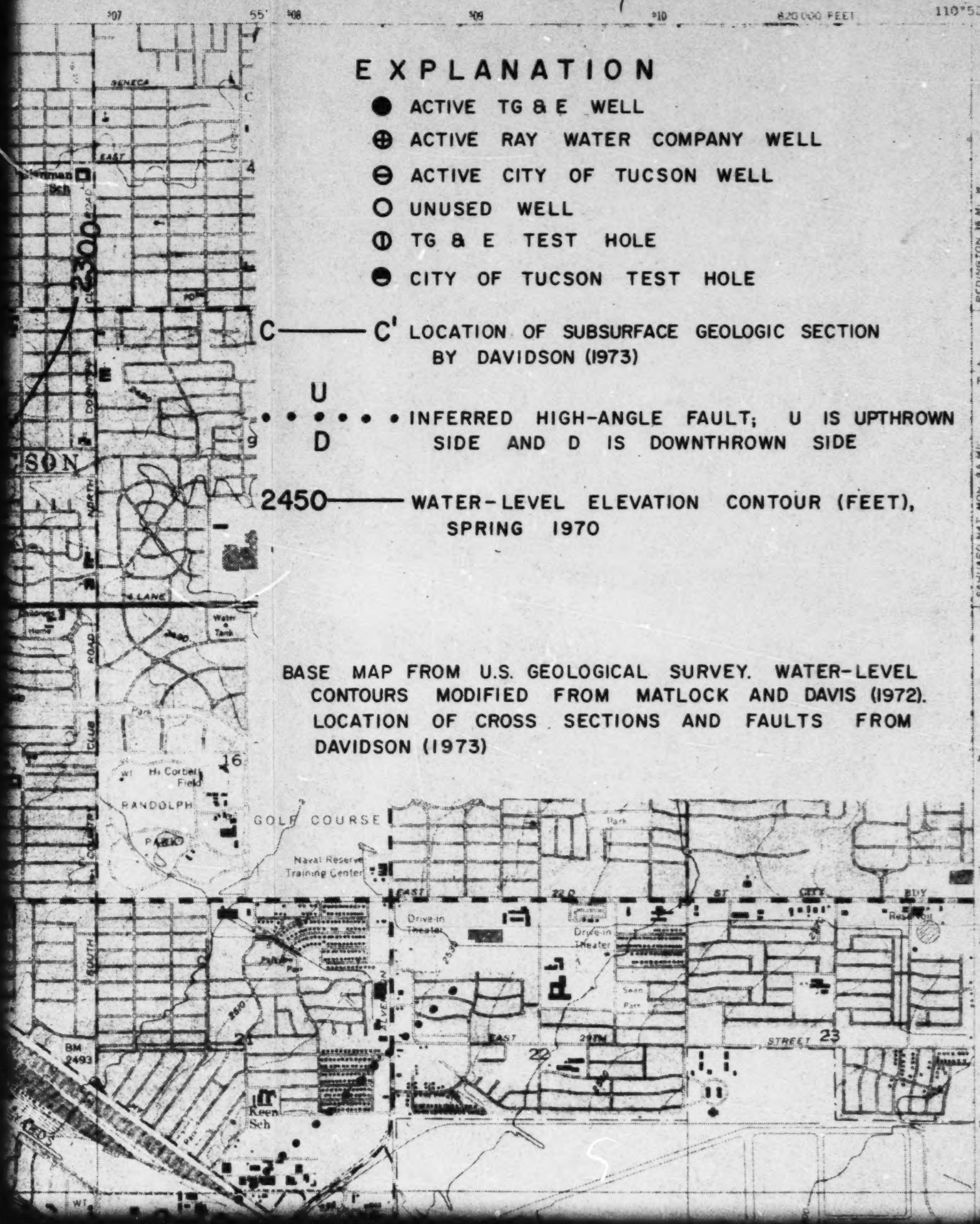
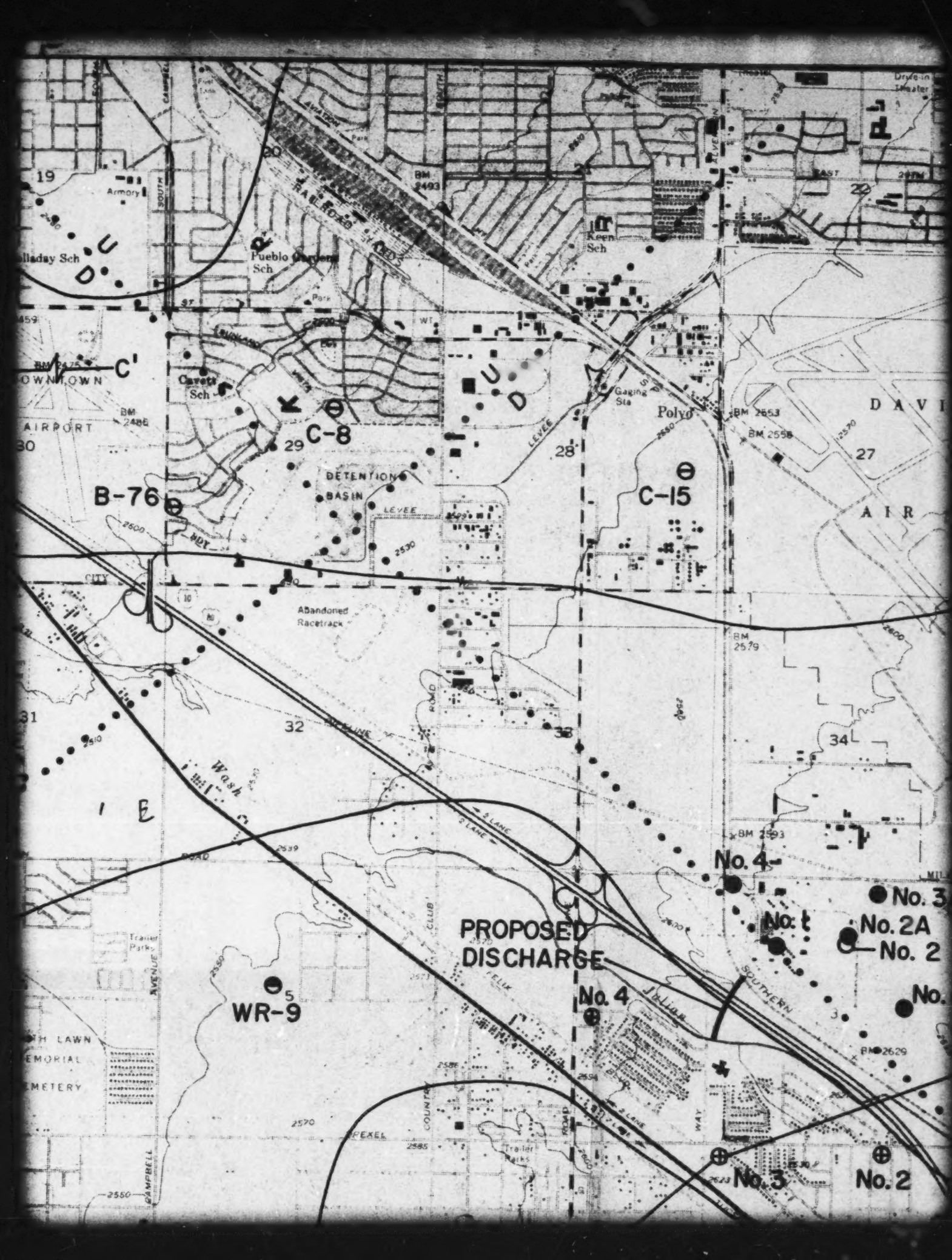
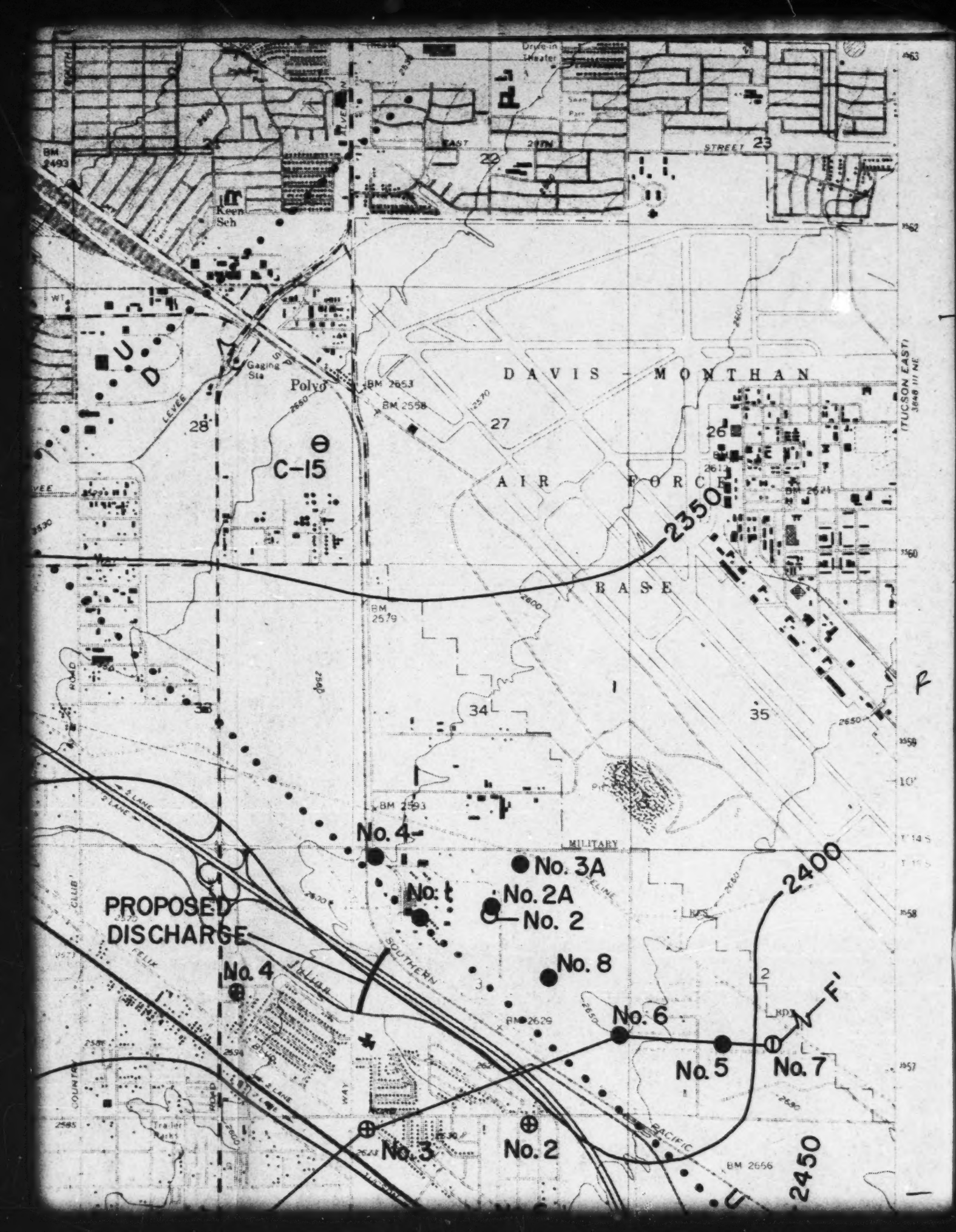

1 B
1948 IV SW
(TUCSON NORTH)
505
507
508
509
Jefferson Park Sch
Polo Village
SS Peter & Paul Sch
Bleeman Sch
Hughes Sch
TUCSON
Mansfield Jr H S
Miles Sch
St Andrews Sch
Robison Sch
Ha Corbett Field
RANDOLPH GOLF COURSE
Naval Reserve Training Center
Drive-in Theater
Armory
Holladay Sch
Pueblo Gardens Sch
Keen Sch
Arroyo
Chico
BM 2493
2300
2450
SPEEDWAY
BROADWAY
4 LANE
EXPLANAT
ACTIVE TG & E
ACTIVE RAY WA
ACTIVE CITY OF
UNUSED WELL
TG & E TEST
CITY OF TUCSO
C C' LOCATION OF SUB
BY DAVIDSON (
U D INFERRED HIGH-
SIDE AND D
2450 WATER-LEVEL
SPRING 197
BASE MAP FROM U.S. GEOLO
CONTOURS MODIFIED FRO
LOCATION OF CROSS SE
DAVIDSON (1973)

FIGURE 2 C


EXPLANATION
ACTIVE TG & E WELL
ACTIVE RAY WATER COMPANY WELL
ACTIVE CITY OF TUCSON WELL
UNUSED WELL
TG & E TEST HOLE
CITY OF TUCSON TEST HOLE
C — C' LOCATION OF SUBSURFACE GEOLOGIC SECTION BY DAVIDSON (1973)
U
D
INFERRED HIGH-ANGLE FAULT; U IS UPTHROWN SIDE AND D IS DOWNTHROWN SIDE
2450 — WATER-LEVEL ELEVATION CONTOUR (FEET), SPRING 1970
BASE MAP FROM U.S. GEOLOGICAL SURVEY. WATER-LEVEL CONTOURS MODIFIED FROM MATLOCK AND DAVIS (1972). LOCATION OF CROSS SECTIONS AND FAULTS FROM DAVIDSON (1973)
SENECA
EAST
NORTH
SOUTH
ROAD
GOLF COURSE
RANDOLPH
PARK
Naval Reserve Training Center
Drive-in Theater
STREET
BM 2493
Keen Sch
Hi Corbett Field
Water Tank
4 LANE
2300
2450
2500
2550
110°52'30"
820000 FEET

SS-19
SS-13
SS-24
B-35
B-32
B-83
WR-1
South Tucson
Pueblo High Sch
Wakefield Jr High Sch
Governor Heights Sch
St John Sch
Lynn Sch
Rose Sch
Van Buskirk Sch
Liberty Sch
Holladay Sch
Mission View Sch
Quiros Sch
VETERANS HOSPITAL
COUNTY FAIRGROUNDS
T. 14 S.
T. 15 S.
SANTA CRUZ VALLEY
SAN XAVIER DEL BAC MISSION 5.6 MI
SELLS 56 MI
NOGALES JUNCTION (ARIZ) 28.6 27 MI
3748 II NE (CAT MOUNTAIN)
USGS Recording Well
420 000 FEET
2350
2D
U.D
Julian Wash
Santa Cruz River
Julian Wash Branch
West Branch
Drexel
Irvington
Ajo
Nogales
Fletcher
Southern Pacific
Tucson
Downtown
Airport
Trailer Park
Gravel Pit
Well
Res
Wells
Drive-in Theater
Cemetery
BM 2389
BM 2459
BM 2486
BM 2522


C'
C-8
B-76
C-15
DETENTION BASIN
LEVEE
Abandoned Racetrack
PROPOSED DISCHARGE
No. 4
No. 3
No. 2A
No. 2
No. 1
WR-9
Pueblo Gardens Sch
Keen Sch
Cavett Sch
Holladay Sch
Armory
Gaging Sta
Polyd
Wash
RAILROAD
AIRPORT
DOWNTOWN
CITY
AVENUE
ROAD
SOUTHERN
Julian
FELIX
CAMPBELL
EXPEXEL
Trailer Parks
Golf Club
BM 2493
BM 2486
BM 2553
BM 2558
BM 2579
BM 2593
BM 2629
19
20
27
28
29
30
31
32
33
34


DAVIS - MONTHAN
AIR FORCE
BASE
C-15
Gaging Sta
Polvo
Keen Seh
Drive-in Theater
STREET
EAST
LEVEE
ROAD
MILITARY
SOUTHERN PACIFIC
Julian
2350
2400
2450
PROPOSED DISCHARGE
No. 1
No. 2
No. 2A
No. 3
No. 3A
No. 4
No. 5
No. 6
No. 7
No. 8
F
F'
BM 2493
BM 2653
BM 2558
BM 2579
BM 2593
BM 2629
BM 2656
BM 2621
(TUCSON EAST) 3648 III NE

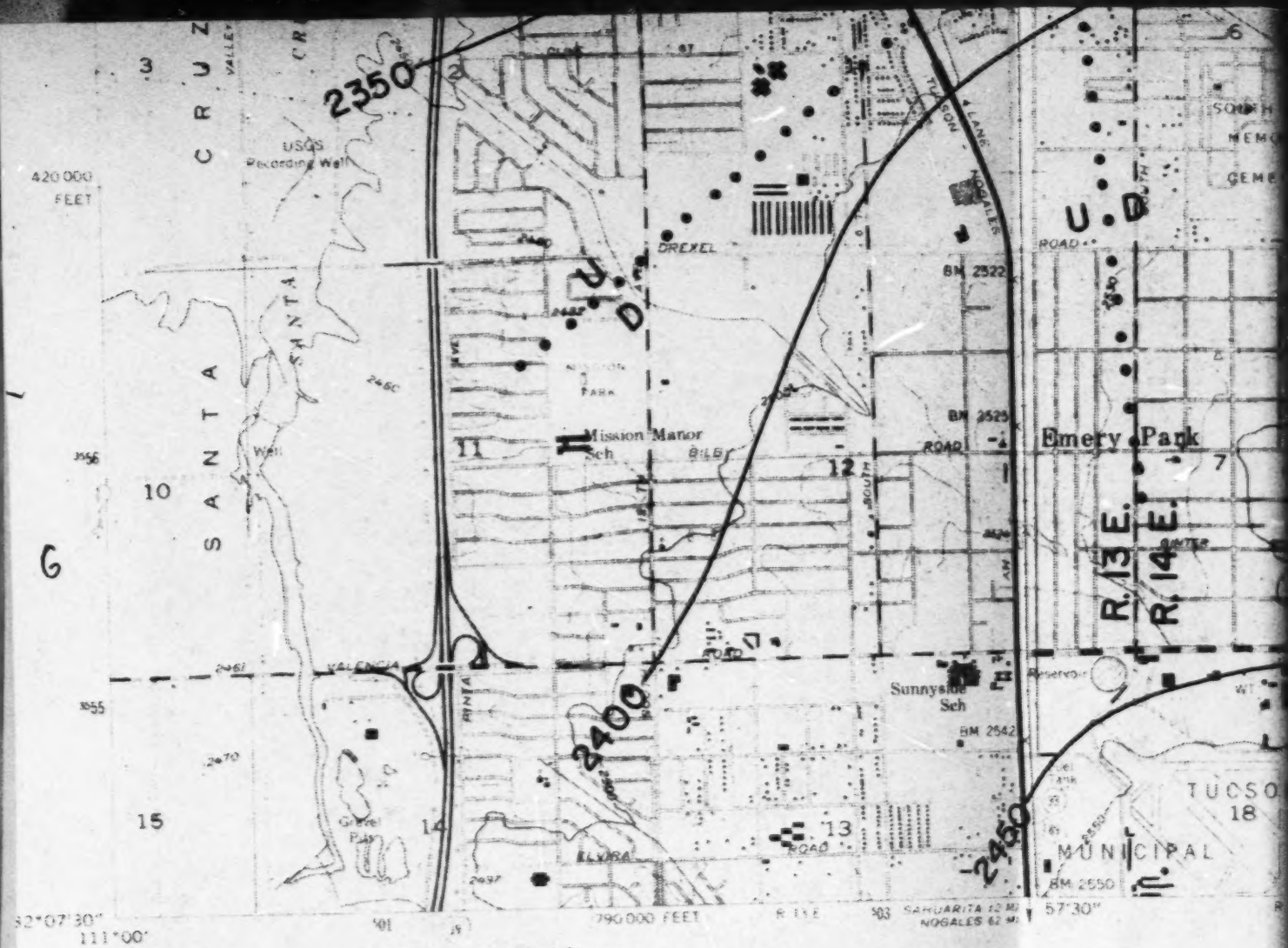


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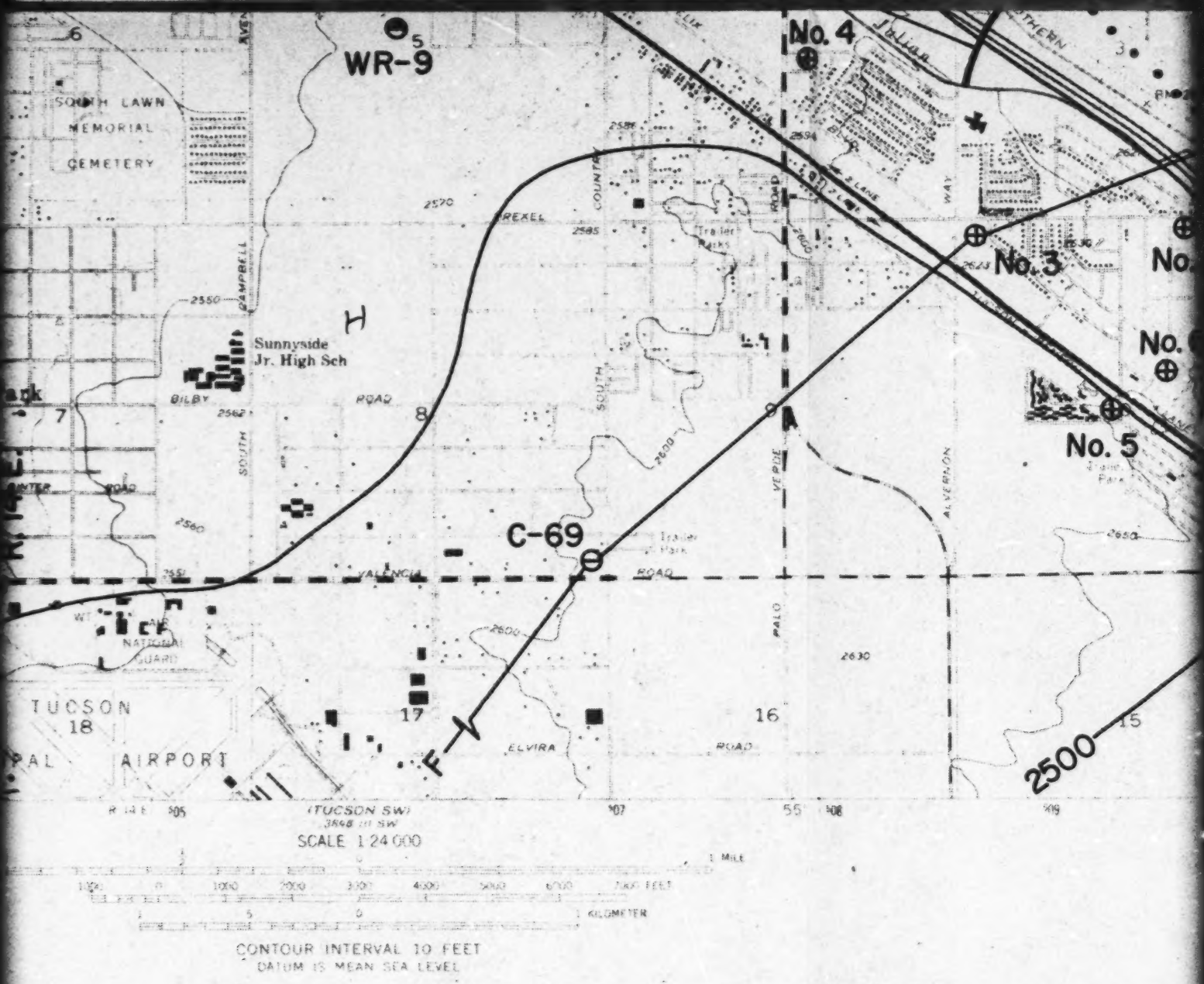
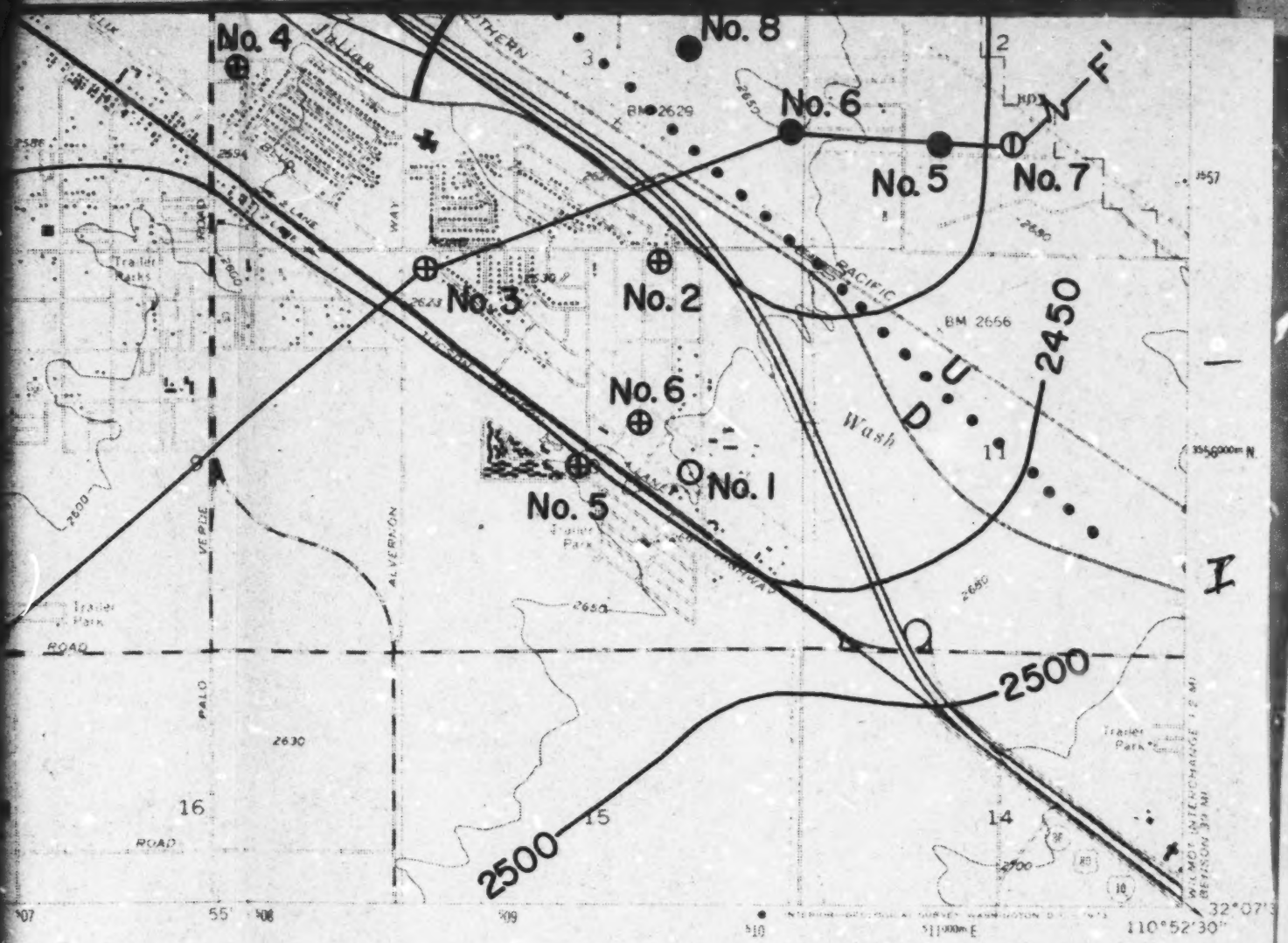
FIGURE 2



E 2.--HYDROGEOLOGIC MAP OF PROJECT AREA.



OF PROJECT AREA.